Precision Agriculture Association New Zealand

TECHNOLOGY FOR SUSTAINABLE GROWTH

PA17 - The International Tri-Conference for Precision Agriculture in 2017

- 7th Asian-Australasian Conference on Precision Agriculture
- 1st Asian-Australasian Conference on Precision Pastures and Livestock Farming
- Digital Farmer and Grower 2017

Monday 16 - Wednesday 18 October 2017

CLAUDELANDS CONFERENCE AND EXHIBITION CENTRE, HAMILTON

The digital future in crop production has arrived

Proceedings of the *7th Asian-Australasian Conference on Precision Agriculture*

16 – 18 October 2017, Hamilton, New Zealand

Warrick Nelson (Editor) – The New Zealand Institute for Plant & Food Research Ltd

Lorraine MacKenzie (Editorial support) – The New Zealand Institute for Plant & Food Research Ltd

The *7th Asian-Australasian Conference on Precision Agriculture* was a conference of PA17 – The International Tri-Conference for Precision Agriculture in 2017

http://doi.org/10.5281/zenodo.1006670

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ABSTRACTS

Presentation

New developments in proximal soil sensing

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http://doi.org/10.5281/zenodo.1001807

This presentation provides an overview of contemporary developments in the field of proximal soil sensing (PSS) as it relates to precision agriculture. The ultimate goal of PSS is to enable low-cost acquisition of accurate information on spatial and temporal changes in soil properties across a landscape. Proximal sensing systems rely on gathering signals from transducers placed in contact, or less than 2 m away, from the target. Knowing and understanding the heterogeneity of soil properties helps farmers and other land managers optimize their decision-making process to develop profitable, sustainable, and environmentally friendly operations. The emphasis will be placed on recent efforts in sensor fusion, when sensors that measure different physical phenomena are integrated in a single platform and/or data acquisition process. The recent development of the on-the-spot soil analyser will be used as an example. Under this framework, several sensing methods will be discussed in more detail. These include digital microscopy, soil gas analysis, visible, near-infrared, mid-infrared, gamma-ray as well as laser-induced breakdown spectroscopy, capacitance and apparent electrical conductivity, and ion-selective membranes. Despite their various limitations, these sensing techniques, together with field topography mapping, have been successfully deployed to rapidly determine an array of important physical, chemical and biological soil properties. The recently developed neighbourhood search analysis software has been used to numerically integrate multiple geospatial data layers and produce field areas representing different sensor measurement combinations as well as locating the most informative calibration sites. The presentation will review several alternative approaches to process PSS data to generate thematic soil maps suitable for site-specific management of seed, lime, fertilizer and other soil amendments.

Poster

Development of data acquisition system for Plum *(Prunus mume) g*rowth monitoring

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General-purpose single-board computers such as Raspberry pi help to develop IoT-based remote monitoring device cheaply and easily, so it is highly utilized to collect data on growing environment and cultivation history of plums for small and medium scale plum farms.

We have developed a remote sensing and data acquisition system using these small single-board computer at a basic stage to analyze the environmental and growth factors that can affect the productivity of plums.

The first prototype used the Arduino MKR1000 to fabricate a data acquisition and transmission module and configured the system using a cloud storage called IoT Makers operated by KT, South Korea's largest telephone company. In order to assess advantages and disadvantages of the data collection device using MKR1000, we conducted an indoor test at the Industrial Machinery Lab at Sunchon National University in 2016. Currently, we are developing a device that uses Raspberry pi as a data acquisition and transmission module.

The final data collection system will be installed in the plum field near Suncheon in 2017 and the actual sensing data will be collected. The collected data will be used to analyze factors related to the improvement of plum productivity.

Remote data collection using low-cost, general-purpose IoT devices will provide the possibility to discover factors related to productivity of various crops as well as plums with low cost and effort.

Poster

Simulation of optimal path planning using modified minimum spanning tree for autonomous agricultural mobile robots

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http://doi.org/10.5281/zenodo.1002355

Background: Autonomous driving is a major issue for precision agriculture. One of important technic is a generate optimum path for autonomous driving. Up to now, autonomous driving technology generated a path that created a least-cost path using only the distance cost. However, in real field large driving radius cause lateral deviation error of mobile robot. Therefore, in this paper, we propose a path planning algorithm base on modified Minimum Spanning Tree (mMST) that takes weight of vehicle radius of gyration into account.

Methods: In this paper we generate optimal path using mMST. First, randomly create nodes in virtual test field. Calculate distance cost, radius of gyration cost between each node. Second, from starting node select next node by considering distance and gyration. Sometime Minimum Spanning Tree (MST) algorithm generate more than 31ink on one node. In this case, path is terminating the driving. The path should be trail or circuit. Repeat the above sequence until all nodes are connected. Before field test simulation was conduct for each path.

Results: In this paper, we applied and simulated MST and mMST algorithms. The cost efficiency according to the turning radius was experimented. Two paths (weight: distance, distance and radius) were generated by each algorithm and the results were compared. Experimental results show that mMST is more superior compared with MST.

Discussions: Future challenges remain to apply this research to real fields. Real field has difficulty to driving because ground condition are uneven and crop damage must be minimized.

Conclusion: The proposed mMST method may resolved that sudden change of direction between the path point causes a large error in the driving of the vehicle. And satisfactory results have been obtained.

Acknowledgement: This work was supported by Korea Institute of Planning and Evaluation for Technology in Food, Agriculture, Forestry and Fisheries (IPET) funded by ministry of Agriculture, Food and Rural Affairs (MAFRA) (No. 714002-07)

Presentation

Development of a method to identify spatial variation in onion crop development and predict yield

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Background: Many factors add to variability and limit the profitability of onion production. Precision management could add value but requires timely capture and processing of crop development data and prediction of yield to inform management decisions. We assessed onion canopies with a range of sensors and sought correlations with yield data. We report results from satellite NDVI and smartphone app percentage canopy cover.

Methods: Mid-season World View 2 imagery at about 5 – 7 leaf stage was processed and paddock NDVI maps prepared. Areas of high, medium and low canopy were identified and relative yields determined at commercial maturity in February. NDVI and yield were compared.

The smartphone app was used to survey a 1 ha crop and canopy cover maps prepared. In parallel, 1m2 plots were photographed at 3, 5, 7 leaf and bulbing, images processed to determine canopy cover. Percentage cover was compared to destructive leaf area and fresh mass measurements.

Results: Strong correlations were found between NDVI and yield which enabled the retrospective creation yield and profit maps, useful for review but not current season management.

Very strong relationships were found between processed smartphone images and measurements of fresh mass and leaf area index.

Discussions: Satellite imagery is expensive at paddock scale, hard to obtain and slow to become available to the manager. However there does seem to be a relationship between early season canopy and harvest yield.

Smartphone imagery can be cheaply gathered and immediately available. The relationship between ground cover and leaf area index suggests potential to create predictive yield maps that may inform current season management such as variable rate fertiliser.

Conclusion: Significant progress has been made, but the considerable variability in onions continues to provide challenges.

Work part-funded by MPI Sustainable Farming Fund and Onions New Zealand.

Poster

Use of real-time remote sensing for engagement to improve water quality outcomes at an on-farm scale

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Targeted Problem: There are possible major land use restrictions in many regions in New Zealand through regional plan changes to improve water quality. These changes will mean farmers will have to change farming practices. It is often hard for farmers to reconcile and quantify their effect on water quality.

Concept/solution to be analysed: Community awareness of water quality has increased exponentially in recent times. There are new water quality limits being set by government in the National Policy statements, which are enacted at a Regional level by regional councils. Many of the contaminants are not obvious or easy to see, and this means there is low trust and engagement in the community.

Methodological approach (Methods): A high level analysis done using GIS will classify land form and business type for the Upper Waipa. Waterways that meet the criteria from this analysis have been selected for a more intensive study. Once this is complete remote sensing sites will be set up that will stay in place and be able to be related to a particular farm(s), and continuously measure various parameters including but not limited to nitrogen, phosphate, temperature, turbidity, and flow 24/7 365 days a year. Intensive imagery collection will support this to help identify and communicate effects seen.

Results: The methodology in this project aims to make the invisible more visible with timely and repeated drone, video and time-lapse imagery, correlated geo-located remote sensing analysed and presented using GIS. The mix of place in space GIS analysis, individual farm imagery, and sensor networks placed in waterways that will only measure water quality parameters attributable to that particular farm will aim to make the invisible visible. Changes in land management will be able to be assessed in real time and actual measured amounts attributable to particular land practices. It is envisaged that this will engage the landowners in adapting their land management to improve water quality as it leaves their farm boundary and contribute to better water quality in the catchments they are in.

Chances for generalization of the Results: The imagery and GIS based data in tandem will greatly assist in communicating the messages of cause and effect and the value of adoption of mitigation in the wider lower Waikato and to further incentivise and demonstrate the value of farm planning to manage risk.

Poster

SensLog - solution for agriculture sensors web

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Agriculture requires the collection, storage, sharing and analysis of large quantities of spatially referenced data. For this data to be effectively used, it must be transferred between different hardware, software and organisations. These data flows currently present a hurdle to uptake of precision agriculture as the multitude of data models, formats, interfaces and reference systems in use result in incompatibilities. Management of huge amounts of data is a challenge. Spatia-temporal data is increasingly collected by remote or in-situ sensors rather than by field campaigns. The wireless communications have several benefits, but also pose challenges to the data exchange reliability and power supply. Sensor calibration and deployment as well as maintenance of sensors need resources and technical skills and increase the costs of data acquisition. Both increasing the amount of data and awareness of data quality issues highlight importance that metadata are attached to sensor data. Senslog is an integrated solution for sensor networks. Senslog consists of data model and server-side application which is capable to store, analyses and publish data in various ways. Senslog receives measured data from nodes or gateways, stores data properly in the database, pre-processes for easier queries if desired and then publishes data through the system of web-services. Senslog is suitable for sensor networks with static sensors (e.g. meteorological stations) as well as for mobile sensors (e.g. tracking of vehicles, human-as-sensor). Database model was based on standardized data model for observations from OGC Observations&Measurements. But the model was extended to provide more functionality especially in the field of users hierarchy, alerts and tracking of mobile sensors.

Presentation

FATIMA Czech pilot

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In FATIMA project, a pilot site in Czechia was established to demonstrate how precision agriculture may serve for optimizing crop yields as well as for protection of water quality, since the pilot is located in Czech largest drinking water reservoir catchment. The pilot site Dehtáře is situated in the south-west Bohemo-Moravian Highland. The site contains tile drainage and is of very heterogeneous soil conditions; from shallow, light and stony Haplic Cambisols to heavy Haplic Gleysols, with profoundly different water regimes. For the field trial (spring barley in 2016), crop yield potential was determined from crop statuses as captured by satellite images) eight years back, assessed by Enhanced Vegetation Index. Based on this, as well as on a detailed soil survey and repeated soil sampling, variable fertilizer application zones (70 – 120%) were delineated and mineral fertilizers distributed accordingly with GPS operated spreader three times from late April to late May. The rest of the site was fertilized uniformly. Soil water regime (soil moisture, soil water potential) was monitored continuously on eight spots and real-time broadcasted by wireless sensor network to WEB GIS interface via SensLog solution, adopted from FOODIE project. In the same spots, soil water was sampled by gravitational soil lysimeters. Precise harvest showed a general agreement with the delineated application zones and yield potential, however, some ambiguities were revealed, most probably due to changeable soil water regime, as documented by the sensors, as well as due to variable soil chemical properties (low soil pH). Nevertheless, precisely applied fertilizer doses in the application zones brought about 10% higher crop yields with simultaneous better N crop efficiency. Soil water quality samples confirmed that heterogeneous doses of fertilizer in correctly delineated zones is a promising approach for improvement of groundwater quality especially in shallow soils with low water and nutrient retention ability.

Keywords: variable fertilizer zones, soil heterogeneity, crop yields

Poster

Farm telemetry

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The effectiveness of each production, including agriculture, is determined by the ratio of the value of the production outputs to the value of production inputs. The goal of project FarmTelemetry is to create a complex machinery effectivity sensing and analysis tools for management support, which will lead to increase of the improved efficiency of crop production by reducing the negative anthropogenic impacts on environment and by reducing the energy consumption and improving carbon balance, while maintaining the level of outputs. The FarmTelemetry analysis are focused on monitoring of activities and utilization of individual tractors. It is also possible to obtain overall overview for individual farmer's fields (blocks). Application currently supports following analysis. • Cultivated blocks - provides list of all farmer's blocks, where the selected tractor was working during the selected day. There is provided information for each of the blocks about spent time and about used passive machinery, if the machinery was equipped with RFID tag. • Utilization - provides information about time the tractor spent by working on farmer's blocks, by moving on other places and by standing in place during selected day. The sum of these times is always 24 hours. • Activities log- provides detailed information about activities of selected tractor during selected day. The log contains information about start time and end time of each activity, location of the activity, used passive machinery and fuel consumption • Overview of activities at field (block)- provides monthly overview for selected field. The overview shows information about sum of times each tractor has spent on selected field including used passive machinery and fuel consumption.

Presentation

Big data in agriculture – from FOODIE towards data bio

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What's the role of Big Data in the farming ecosystem? Farmers need to measure and understand the impact of a huge amount and variety of data which drive overall quality and yield of their fields. Among those are local weather data, GPS data, ortophotos, satellite imagery, soil specifics, soil conductivity, seed, fertilizer and crop protectant specifications and many more. Being able to leverage this data for running long and short term simulations in response to "events" like changed weather, market need or other parameters is indispensable for farmers in terms of maximizing their profits. IoT (Internet of Technology) including field sensors and machinery monitoring. The experimentation in FarmTelemetry project demonstrates that one average Czech farm (i.e. around 1'000 hectares) could generate daily 20 MegaBytes of data. This could be only for Czech Republic something between 30 and 50 GB per one day. We may easily reach Terabytes of data a day from agricultural basic monitoring by sensors in Europe. Together with satellite data agriculture will need to manage extremely large amount of data. On one side there is growing whole ecosystem with a strong need to secure Big Data from different repositories and heterogeneous sources. In some cases, sharing of data could be common interest, but on other side, there are also different interests and data could help to one part of value chain to take bigger part of profit. From this reason Big data are sensitive topics and trusting of producers about data security is essential. The producers of seeds and chemicals want to maximize their business with farmers. Our team stated implementation of Big Data technologies in frame of European 7FP project FOODIE. This work currently the work continue as part of DataBio project.

Presentation

Software development of STS miniature spectrometer for crop monitoring system

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In order to predict the nutrient content of crop non-destructively and quickly, a spectrum analyzer was developed to measure the spectral reflectance of 350-800 nm in this paper. The system has three parts: optical sensor, data transmission module and the controller. Spectral information collection software includes three modules: acquisition parameters, acquisition control and data management. Calibration experiment and application experiment were carried out to test the performance of the spectrum analyzer. The correlation was analyzed between the spectral reflectance measured by spectrum analyzer and ASD Field Spec Hand Held 2. The result showed that the average correlation coefficient value was 0.94. It was used to detect the chlorophyll and moisture content of potato. The SPAD regression model was established and the determinant coefficient R2 was 0.484, moisture content regression model was established and R2 was 0.735. Results showed that the device has a certain ability to predict chlorophyll content and moisture content of potato leaf.

Poster

Basic tests for automatic nutrient monitoring for hydroponic crop production system

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http://doi.org/10.5281/zenodo.1002271

Background: Recently around the world, the global climate change caused the decrease in the food production. Besides this, traditional farming and amount of cultivable land are also decreasing. As an alternative to these problems, more attention is paid to the plant factory. Automated nutrient sensing and control for plant factory (e.g., closed hydroponic system) would allow more efficient use and management of nutrients for crop production. An attempt has been taken to test the components along with the nutrient management system for plant factory.

Methods: The nutrient management system was divided into two parts - sensing and controlling part. First, a data acquisition code was made using Lab View 2011. Using NI USB 6009 device, performance of EC, pH, NO_3 and K ion selective electrodes were checked by measuring the correlated components in standard and real-time nutrient solution. A mixing algorithm was developed to control the individual solution volume to be supplied depending on their concentration in the mixing tank.

Results: The EC, pH, NO_3 and K sensors were tested in a standard solution of 3, 4, 100 mg L^{-1} and 10 mg L^{-1}. Standard deviations after calibration and regression between before and after calibration were 0.189, 0.245, 1.371, 1.400 and 0.902, 0.885, 0.829, 0.861 for EC, pH, NO_3 and K sensors, respectively. After rinsing the standard error reduced to 16.69% and 42.16% for NO_3 and K ISE sensors, respectively.

Discussion: Errors occurred due to signal drift and bio-film formation in the sensors head. Signal processing algorithm would be developed to remove these errors.

Conclusion: An ISE-based, computer-controlled nutrient maintaining system would be a viable technique for improving accuracy and precision application of nutrient solutions in a plant factory crop production system.

Presentation

Soil apparent electrical conductivity sensor data for estimation of CI-based soil compaction status

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http://doi.org/10.5281/zenodo.895331

Regionalization of soil properties is very important for successful site-specific field management. Soil compaction is a critical issue to be detected and managed due to its effects on crop growth. Soil compaction has been conventionally quantified as cone index (CI) measured by an ASABE-standard cone penetrometer, but this approach has limited capability of obtaining the spatially-dense data required for precision agriculture. A significant amount of past research has related CI with apparent soil electrical conductivity (ECa), and recently the potential of ECa to estimate subsoil compaction status through the stress-at-rest-coefficient (K0), defined as the ratio of normal compaction and pre-compaction, was introduced. The objective of this study was to explore the potential of relating K0 with ECa using data obtained from sites with wide ranges of soil texture, bulk density, and water content, properties that significantly affect both CI and ECa. The following data was collected from 35 sites in Missouri and Illinois fields: CI profile up to 75 cm with a 5-cm interval, ECa measured by EM38 and Veris devices, and depth-dependent soil properties such as soil texture, bulk density, and water content. First, K0 values were calculated from CI profiles by depth and related to ECa measurements. Then, effects of the soil properties on the relationships between K0 and ECa were investigated. Results of this study will provide insights on the effects of soil properties on soil compaction, and on the potential to use ECa to estimate the status of soil compaction.

Presentation

Real industry technology learning systems for tertiary teaching

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A collaborative project between seven universities, the SmartFarm Learning Hub (the Hub) aims to increase the knowledge and skill base of students studying agriculture and agribusiness in the latest agri-tech tools and systems. One motivation for the Hub is the current skills shortage in the agricultural industry and the challenge for university education to keep pace with the rapidly developing agri-tech systems and tools. The Hub will host numerous learning modules which use real industry technology learning systems (RITLS) using real-farm data allowing students to learn how to apply industry developed or commercially available systems and tools to solve an agricultural problem or manage a complex system. By completing these learning modules, students' capability and readiness for employment within the agricultural industry will be increased. Reported are the evaluation of responses from students after completing the ProductionWise® learning module to the questions based on their perception of employability skills and practical content. Initial results demonstrate that the majority of students believe the content of the ProductionWise® practical is accurate and up-to-date with 87.5% of respondents either 'strongly agreeing' or 'agreeing' with this statement. The feedback received from students will used to improve the instructions and content of the practical for future cohorts.

Presentation

Is big data driving a paradigm shift in precision agriculture?

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In recent years there has been considerable debate about the significance of the digital explosion for precision agriculture (PA). Much of the discussion focuses on whether the arrival of big data signals the emergence of or need for a new paradigm. Answering such questions requires historical analysis. In order to determine where PA research is now and where it may go in the future, we need to understand where it has come from and how it has developed. This paper brings together a new collection of statistics depicting recent trends in PA and the structure of scientific production based on bibliometric data from Scopus and other selected sources. The results should provide a valuable resource of bibliometric indicators for researchers and policy-makers working in the field of PA.

Presentation

Environmental and food safety considerations in precision agriculture

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http://doi.org/10.5281/zenodo.893658

Precision agriculture and Good Agricultural Practices (GAP) cover a number of activities that relate to food safety, appropriate use of chemicals and reduction of the residue level on food crops, minimal negative impacts of agricultural production on the environment, and occupational safety and welfare.

In a review current and future potential environmental and food safety contributions are discussed. Quantitative information on environmental benefits from precision agriculture technology is discussed nitrogen application, weed control and pest and disease control. Potential environmental benefits from implementation of other precision technology in combination with changing agricultural practices are listed.

In conclusion, technology development and precision agriculture will have benefits for consumers in terms of a more efficient healthy production with lower chemical inputs and reduced environmental risks.

Presentation

A cognitive decision tool to optimise integrated weed management

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http://doi.org/10.5281/zenodo.895617

Weed management is becoming more complex due to the rise of herbicide resistant weeds. Integrated weed management strategies are recommended to minimize herbicide resistance. However, weed management can be daunting and uncertain leading to biased, avoidant or suboptimal decisions. Existing weed management tools can be insensitive to user needs and changing contexts over time. This paper discusses a proof of concept cognitive tool for integrated weed management decisions.

Our team has taken initial steps into the design of an interactive tool for cotton growers that allows them to explore the impact of individual priorities and strategy preferences (optimistic, pessimistic and risk related) on weed management decisions given uncertainty in temperature and rainfall. Our research tackles the challenge of engaging stakeholders in complex decision making in three ways: 1) recognizing individual cognitive priorities 2) visualising scientific weed management in an appealing mobile interface and 3) representing decision uncertainties and risk weighted against cognitive priorities.

Specifically, our tool communicates personalised barnyard grass weeding management strategies for pre-crop and in-crop cotton weeding decisions. We ranked a set of actions including applications of herbicides: glyphosate, paraquat (shielded and unshielded), group A, trifluralin, diuron, pendimethalin, s-metolachlor, fluometuron, glufosinate; and non-chemical methods such as soil disturbance at various times prior to planting, at planting and in crop. Each action was evaluated against personal priorities including: saving time/effort, health/safety, saving money, sustainability and effectiveness.

The adoption of decision support in AgTech is improved when users can represent the objective benefits of recommended actions proportionately to their own needs and measures of success. Our interactive decision tool provides individualised decision support and quantifies uncertainty about attributes relevant to decision-makers to optimise integrated weeding management. The framework, however, can be extended to other decision making context where user priorities and decision uncertainties need to be incorporated alongside scientific best-practice.

Presentation

Automated pollination of kiwifruit flowers

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http://doi.org/10.5281/zenodo.895619

This paper contains the initial evaluation of a novel platform mounted robotic pollination system. Advancement in artificial pollination is an important step forward in agricultural sectors due to the global decline of natural pollinators. Robotic pollination allows for potentially autonomous, precision operation; however, background research suggests prior development in the area is sparse. The featured wet-application robotic pollination system can detect 89.3% of flowers, correctly localise 71.9% of flowers and hit an estimated 80.1% whilst driving at a 0.36 m/s through kiwifruit orchard rows.

Key words – Pollination; Robotics; Detection; Kiwifruit; Horticulture

Presentation

Custom-built wireless sensor networks to monitor soil moisture

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http://doi.org/10.5281/zenodo.893654

The temporal change of soil moisture storage is one of the most critical pieces of information required for efficient irrigation management. Measurement of soil moisture in the past was very expensive and accounting for spatial variability was largely impractical. Recent technological developments now make it possible to monitor soil moisture in near real time using wireless sensor networks. This paper presents a successful application of custom-built wireless mesh sensor networks based on DigiMesh protocol, a proprietary technology developed by Digi International Inc. to monitor spatial distribution of soil moisture in near real time. Our system is designed to transport the measured data from wireless sensor networks in the field to cloud data base servers over cellular networks or Iridium satellites. Data are then processed to make them available on smart phone-compatible web browsers in near real time to help practitioners plan their precision irrigation scheduling.

Presentation

Multi-thematic delineation of 'natural zones' of arable fields and their correspondence to spatial yield variation

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http://doi.org/10.5281/zenodo.893670

Properties such as soil apparent electric conductivity (ECa), topography and other site-related data (e.g. canopy reflectance from aerial images) vary across field. The agronomic effects of such variability can sometimes be seen in the spatial variations of crop yield on that field. However, yield maps do not always represent the natural boundaries based on site characteristics. Identification of these boundaries as "management zones" (MZ) can be beneficial in crop management and improving crop input use efficiency. A simple methodology is required to delineate such zones. This research presents an effective methodology to delineate MZ in an irrigated and a non-irrigated (rain-fed) arable maize field in New Zealand. Elevation data for the sites were acquired from Google Earth images and a soil survey. Soil ECa was collected from a soil survey with an electromagnetic device. Yield values (t/ha) were obtained from combine harvesters equipped with yield monitor and Global Positioning System (GPS), over the course of four years for the irrigated site, and two years for the non-irrigated site. The yield data was quality controlled using a filtering system to remove outliers and technically non-plausible data. The data sources were combined in Geographic Information Systems (GIS) and three MZ were delineated for each field through standard clustering methods. The maize yields were aggregated per derived MZ to compare yields between different MZ-classes. The results showed that there was some consistency in yields related to the MZ, derived without yield data. In both the non-irrigated and irrigated fields, the lowest yield consistently occurred in the same class each year, however, the MZ-class with the highest yield varied year to year. The results show that it is possible for the studied type of fields to delineate 'natural' clusters or zones of site properties that can be used as MZ-classes as they represent different yield levels. The required inputs are freely available and easily obtained data.

Presentation

Soil electrical conductivity imaging of the soil profile and its relationship to soil properties

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http://doi.org/10.5281/zenodo.891095

The variability of soil properties in space and time is a challenge to their measurement. Currently, apparent electrical conductivity (ECa) of the soil profile can be used to estimate indirectly the spatial variability of the soil properties: salinity, texture, cation-exchange capacity and moisture content. An electromagnetic induction sensor does not require direct contact with the ground, and data collection is relatively easy, rapid, and inexpensive. This allows a larger number of measurements and more comprehensive coverage of sites than is possible with traditional soil sampling methods.

A quasi-2D electromagnetic conductivity model for a field site was developed using electrical conductivity (ECa) data measured by a multi-coil DUALEM-421 sensor and a DUALEM-1s sensor.

Relationships of estimated ECa with volumetric water content (Θv) and cation exchange capacity (CEC) were reasonably accurate (R2 = 0.62 for DUALEM-421 and 0.58 for DUALEM-1s and R2 = 0.68 for DUALEM-421 and 0.58 for DUALEM-1s for Θv and CEC, respectively). These relationships were used to derive depth profile images. As expected, Θv, CEC and the estimated ECa follow similar trends down the soil profile. This soil ECa imaging method shows good potential for predicting 2D depth profiles of certain soil properties.

Poster

Compressive sensor fusion of weather data

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Background: Water management is increasingly important. The better you can estimate evaporation losses, the better you can apply irrigation. Empirical formulas for evaporation rely on weather data such as temperature, wind speed, relative humidity, and insolation.

These can be measured by sensor networks. To reduce the cost of operating a sensor network, people use low power devices and seek to reduce radio transmission costs, which also extend service time.

Several compression schemes exist but are mostly application-independent. Using different compression for different measures helps. We are exploring two issues: how much does knowing how the data will be used let you transmit less accurate or less timely data? And can data from one node improve modeling at nearby nodes and overall compression?

Goal: to save power without sacrificing quality.

Methods: We are using a year's NIWA and other weather data from three nearby stations. Given an empirical formula, it is straightforward to derive how timely and accurate the measurements need to be. Given those figures, it is straightforward to run a model-based compressor and determine the transmission costs for a single node.

The next phase will look at sensor fusion algorithms such as the Brooks-Iyengar, trading off fault tolerance against reduced transmissions.

Results: Preliminary **Results:** simple models can yield 10-90% compression depending on consumer's accuracy and timeliness needs. Sometimes nearby stations have similar measurements, sometimes not, so we intend to develop an adaptive fusion algorithm.

Discussions: The methods will need to be tested on other data sets and on other applications, such as frost warning. The search for simple techniques is most important for low-power devices.

Conclusion: This research only began but already shows that transmission costs can be reduced up to 90%. Next task is to maintain these exceptional results in the presence of faults and microclimate differences.

Presentation

A big data approach to predicting crop yield

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http://doi.org/10.5281/zenodo.893668

Many broadacre farmers have a time series of crop yield monitor data for their paddocks which are often augmented with additional spatial data such as gamma radiometrics surveys or ECa (apparent soil electrical conductivity) from an electro-magnetic induction survey (EMI). In addition there are now readily available national and global datasets which can be used to represent the crop-growing environment. Rather than analysing one paddock at a time, there is an opportunity to explore the value of combining data over multiple paddocks and years into one dataset. Using these datasets in conjunction with machine learning approaches allows predictive models of crop yield to be built. In this study we explored this approach with a particular emphasis on the forecasting ability of the models based on pre- and mid-season information from predictor variables. Several large farms in Western Australia were used as a case study. Yield from wheat, barley and canola crops from 3 different seasons that covered ~15,000 hectares in each year were used. The yield data was processed to a 10 m grid, and for each observation we built an associated space-time cube of predictors. This consisted of grower collected data such as EM and gamma radiometrics surveys, and nationally available data such as MODIS NDVI, and rainfall. Random Forest models were used to predict crop yield of wheat, barley and canola using the space-time cube. Three models were created based on pre-sowing, mid-season and late-season conditions to explore the changes in the predictive ability of the model as more within-season information became available. These time points also coincide with points in the season when a management decision is made, such as the application of fertiliser. The models were evaluated using cross-validation based on paddocks and years and this was assessed at the spatial resolution of the paddock. The models performed better as the season progressed, largely because more information about within-season data became available (e.g. rainfall). Cross-validated results showed the models predicted yield very accurately, with an RMSE of 0.36 to 0.42 t/ha, and an LCCC of 0.89 to 0.92 at the paddock resolution. The more years of yield data that were available for a paddock, the better the predictions were. The generic nature of this method makes it possible to apply to other agricultural systems where yield monitor data is available. A data-driven approach to predicting crop yield as an alternative to using mechanistic models has several advantages. Future work should explore integration of more data sources into the models and focus on using the models to inform management decisions such as fertiliser applications.

Presentation

Crop yield estimation using deep learning

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http://doi.org/10.5281/zenodo.893710

Effective crop load management in orchards is a requirement for accurate crop yield estimation. Traditionally this involves various methods of obtaining a measure of the fruit tree features that predominantly determine crop yield (wood, buds, flowers, fruitlets, and fruit). Manual counting of fruit, flowers, or fruitlets during various stages of growth is a laborious and expensive process and often suffers from significant inaccuracies. While optical approaches to automated fruit counting have been proposed they are usually not robust to changing light conditions or colour and shape changes of the fruit during the growing season.

We are currently developing an automated yield estimation system that optically estimates crop yield in orchards during various stages of growth. Instead of using traditional machine vision and image processing algorithms we build on recent advances in convolutional neural networks (CNN) to build an object detector that extracts regions from the image that represent a fruit. The same framework can also be used to detect leaves, branches or other parts of the orchard canopy. These results can then be used to estimate yield using a statistical modelling approach.

Presentation

Estimation of the actual evapotranspiration in olive orchard using a two-layer model integrating climate and satellite data

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Traditionally, irrigation labor considers the value of reference evapotranspiration (ETo) and crop coefficient to estimate actual evapotranspiration (ETa). This methodology presents significant errors in the obtention of Kc. To avoid using empirical values of Kc, some authors suggest using two layer models to estimate ETa over sparse canopies such as olive orchards. However, the model does not consider the effect of spatial variability corresponding to the size of the canopy, leaf area index (LAI) and fractional coverage (fc) on the quantification of ETa. For this reason, a study was carried out to estimate ETa using the Shuttleworth-Wallace (SW) model over a drip irrigated olive orchard using as inputs climatic and satellite data. The experiment was performed over a 6.45 ha, processing 7 Landsat images acquired from 2009 to 2010. The information was used to calculate instantaneous net radiation (Rn_i) and instantaneous soil heat flux (G_i), which estimated the instantaneous available energy (A_i). The SW model performance was compared with the eddy-covariance (EC) method. Results indicate that ETa estimated through climatic and remote sensing information (ET_{sw1}) shows an error of 10% with a RMSE and MAE values of 0.31 and 0.28 mm day-1 respectively. For ETa estimated through climatic information (ET_{sw2}) an error of 10% and a RMSE 24% higher than ET_{sw1} was observed, showing that the use of spatially distributed variables such as Rn_i and G_i could improve the performance of the proposed model.

Poster

Distribution uniformity of blended vs. independently metered granular fertilizers using a variable-rate spinner disc spreader

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Background: Broadcast fertilizer distribution using spinner-disc spreaders equipped with variable-rate technology has become a widely adopted practice. However, a few spinner-disc spreaders provide dual bins permitting the independent metering of two products. The questions at hand does the individual fertilizer distribution pattern vary if two products are applied in blended form or independently metered onto the spinner discs. Therefore, this study compares the distribution uniformity of a common phosphorus and potassium fertilizers applied using variable-rate technology in blended versus independently metered forms.

Methods: A common US spinner-disc spreader with a dual bin, and the ability to independently meter two products onto the spinner-discs was used for this study. Prior to spreading fertilizer, particle analysis determined that the bulk density of diammonium phosphate (DAP), muriate of potash, and a blended fertilizer (10-26-26) were 1009, 1105, and 1025 kg m-3, respectively. All three fertilizer mixtures were broadcast and nutrient distributions determined using standard procedures. Different spinner disc speeds (600, 700 and 800 RPM) and application rates (220 and 440 kg ha-1) were included as treatments.

Results and discussions: Results indicated differences between independently metered DAP and potash versus blended. Distribution patterns did not vary at the different application rates. Also, it was found that the application rate and divider position had no effect on the efficiency of fertilizer distribution, while the disc speed improved distribution uniformity.

Conclusion: These results indicate that while spinner-disc spreaders are inefficient by nature, opportunities exist to increase distribution uniformity through using newer technology such as dual bin spreaders.

Poster

Turning control of a mobile robot for greenhouse spraying

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http://doi.org/10.5281/zenodo.1002868

The road of a greenhouse is both damp and narrow, and there are both ground obstacles and space obstacles in a greenhouse, which easily cause the instability problem for a four-wheel independent driving greenhouse spraying mobile robot turning in the greenhouse. In order to improve the steering performance of the greenhouse spraying mobile robot, based on the characteristics that each wheel torque of the robot can be separately controlled, the dynamic model of the four-wheel independent steering system is firstly established by using the D'alembert's Principle and choosing the sideslip angle and the yaw velocity as the state variables. Then, based on the theory of sliding mode control, a dynamic sliding mode control strategy with exponential approaching rate is proposed by adopting the sideslip angle and the yaw velocity as the joint control variables in order to make the sideslip angle be in the stable range and make the yaw velocity track the desired value well. Finally, the simulation of the steering performance is performed using Matlab/Simulink. The control response curves of the yaw velocity and the sideslip angle of the robot's mass-center in a step input and in a sinusoidal input are obtained respectively. It is shown from the simulation results that compared with the feedforward-feedback control method, the proposed dynamic sliding mode control strategy based on the established dynamic model is effective to improve the turning control stability of the mobile robot for greenhouse spraying. The experiment results further verify the feasibility of the proposed turning control strategy.

Presentation

rmAgro, a reference model for data exchange in precision agriculture

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http://doi.org/10.5281/zenodo.893666

From the start of information technology onwards there is a need to exchange data between different software components and as soon as they are developed by different parties there is a need for standard methods. One of the successful standards is ISO11783 for data exchange between implements and towards Farm Management Information Systems. However, with the introduction of new sensor systems and IoT, independently developed advisory systems and requirements for tracking and tracing, there is a need for standards covering a wider scope as above mentioned one.

We started in the Netherlands in 2010 with as basis the first reference model for crop production, IMOT (1986). The data part of the reference model drmAgro, is set up as a Platform Independent Model (PIM) following UML. This PIM is transformed to specific models, like an XML model, a Java interface model and a DDL model for databases. Transformations to other languages are possible and a transformation to an OWL model is under development. The objective is to keep the specification of agricultural objects independent of the technology used for implementation. Care is taken that content of other models like ISO11783-10, AgroXML, Edaplos, Inspire and most recently ADAPT, is mappable to drmAgro.

The result is a public available platform independent reference model which is and will be in continuous development. It is set up with a generic package and branch specific packages like crop production, greenhouse production and animal husbandry. Crop production covers a wide range of use cases like planning and reporting of fieldwork, providing advice, soil sampling and analyses, application of crop growth models, scheduling of farm operations, auditing, etc. This reference model is the basis for standardised SOAP/XML messages exchanged between farm management systems and advisors, processors and the government in the Netherlands. It is also the basis for REST/XML data exchange through the FIspace platform developed as an EU project.

As mentioned above, there are different models intended as basis for standardised data exchange and many more proprietary interfaces defined. With globalisation of services in agriculture the need for one common basis will grow, while technology will continue to change. This requires a basis with clear semantics which is technology, platform, and independent.

rmAgro has proven to be a solid basis for implementation of standardised data exchange through SOAP webservices in the Netherlands, and REST based message exchange in the FIspace project.

Presentation

A review of practices in precision application of granular fertilisers

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http://doi.org/10.5281/zenodo.891516

There is an implicit assumption in cited literature on precision agriculture (PA) that spreading of fertiliser is performed perfectly in the field leading to uniform application, this is not true. Variation can be large and often the actual performance of spreading equipment used has never been measured or verified. In various countries around the world there are quality assurance (QA) systems designed to achieve a prescribed level of performance. Even within these QA schemes limited testing is undertaken and always under perfect or near perfect conditions.

The test methods are designed to establish an acceptable bout width which meets an acceptable evenness of spread if driven accurately. The test does not take into account wind conditions (except for requiring less than 15kmhr-1 for testing), humidity, slope, terrain or the instrumentation to maintain the desired bout width.

This paper examines the effect of the farm environment and the physical characteristics of fertilisers on the spread patterns of fertilisers in the field. Fertilisers with heterogeneous particle size distributions proved to have more robust spread patterns under field conditions than those with homogeneous particle size distributions.

Presentation

Integrating soil moisture measurements into pasture growth forecasting in New Zealand's hill country

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Forecasting pasture growth in hill country landscapes requires information about soil water retention characteristics, which will help to quantify both water uptake, and its percolation below the root zone. Despite the importance of soil moisture data in pasture productivity predictions, current models use low-resolution estimates of water input into their soil water balance equations and plant growth simulations. As a result, they frequently fail to capture the spatial and temporal variability of soil moisture in hill country soils.

Wireless Sensor Networks (WSN) are promising in-situ measurement systems for monitoring soil moisture dynamics with high temporal resolution in agricultural soils. This paper presents the deployment of a soil moisture sensing network, utilising WSN technology and multi-sensor probes, to monitor soil water changes over a hill country farm in the northern Wairarapa region of the North Island. Processed capacitance-based raw data was converted to volumetric water content by means of a factory calibration function to assess sensor accuracy and to calculate soil water storage within the pasture root zone.

The derived volumetric soil moisture data was examined in terms of its dependence on the variability and influences of hill country landscape characteristics such as aspect. The integration of spatially distributed sensors and multi-depth soil moisture measurements from various hillslope positions showed that slope and aspect exerted a significant impact on soil moisture values. Furthermore, considerable differences were identified in soil water profile responses to significant rainfall events and subsequent soil water redistribution.

Initial indications are that high-resolution time series of accurate multi-depth soil moisture measurements collected by a WSN are valuable for investigating root zone water movement. Sensor evaluation and data analysis suggest that these devices and their associated datasets are able to contribute to an improved understanding of drying and wetting cycles and soil moisture variability. Potentially, this will create an opportunity to generate improved pasture growth predictions in pastoral hill country environments.

Presentation

Precision Technologies: Maximising the value of irrigation

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http://doi.org/10.5281/zenodo.893656

Precision irrigation, by definition, reduces water losses and increases water productivity from irrigated land. This is required as global freshwater scarcity continues to escalate. The concept of precision irrigation can be applied simply and without technology in lower income regions. However, research shows that significant benefits are gained when precision sensor mapping is used to define soil spatial variability, derive management classes, guide placement of sensors for monitoring, and provide timely information for precision irrigation scheduling.

Results from research trials on commercial farms using variable-rate sprinkler irrigation systems with individual nozzle and speed control, used with sensor mapping and monitoring technologies indicate water savings (typically 5–30%, depending on the degree of variability), a major reduction of irrigation-related drainage events, and positive or neutral impact on crop yield. The systems are also used innovatively by farmers for flexible management (e.g. multiple crops under one system; pasture renovation of small irregular areas, precision grazing). This paper presents a case study to demonstrate how precision irrigation practices can be used for best management of irrigation onto variable soils to enhance crop yield and minimise irrigation-related drainage losses.

Presentation

Laser ultrasonic monitoring of the elastic properties of an apple

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http://doi.org/10.5281/zenodo.893708

Fruit firmness estimates usually require contacting or destructive methods. However, we propose to estimate firmness from an all optical, non-contacting method that generates and detects elastic waves in an apple. The compressional and shear wave velocities are governed by the fruit's elastic constants and density, which can be used to estimate firmness, non-destructively. High energy pulses of light are used to excite elastic waves via thermo-elastic expansion. Elastic waves are detected using a laser Doppler vibrometer. By exciting the apple surface at many locations we accurately estimate the compressional, shear and Rayleigh wave velocities of an apple. Repeated realizations of this experiment over 15 days to observe changes in apple elastic properties over time. Softening of the apple decreases the resonant mode frequencies and elastic constants, as well as increases wave attenuation. We find that attenuation is the most sensitive parameter to the aging of the apple. We believe that our novel method of apple interrogation could be automated, and extended to other fruits.

Presentation

Transforming variability to profitability – variable seed rates in New Zealand maize

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http://doi.org/10.5281/zenodo.893706

The use of variable rate seeding (VRS) in arable crops to match seeding rates to areas with homogenous paddock performance, known as Management Zones (MZ) is widespread worldwide. However, VRS has not been undertaken in commercial maize crops in New Zealand. This paper outlines a single maize VRS trial carried out in the 2015/16 growing season in the Waikato, New Zealand, to investigate the relationship between different seeding rates and MZ to maximise crop yield, but also gross margin (GM). This work shows that the use of MZ and VRS can provide a relatively simple, practical way of improving maize crop gross margin in a New Zealand paddock. Given the importance of farmers ensuring the minimisation of nutrient loss, we also believe that VRS is a valuable tool to minimise losses due to nutrient over-supply to poor performing zones in maize crops.

Presentation

Precision agriculture for New Zealand potatoes – effect of variable yield, tuber size and income

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This paper integrated geospatial soil and potato crop harvest characteristics to analyse geospatial crop profitability, and to aid crop management decision-making processes in future years.

Poster

Evaluation of bacterial leaf blight of rice using hyperspectral data

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Bacterial blight is one of the most serious diseases of rice. Yield loss due to bacterial blight can be as much as 70% when susceptible varieties are grown in environments favorable to the disease. The Government of Indonesia has launched agricultural insurance program since 2013 for damage of rice by drought, flood and pest and disease. A key in agricultural insurance is damage assessment which is required to be as precise, quick, quantitative and inexpensive as possible. Conventional method is to inspect the damage by human eyes of specialist having experiences. This method, however, costs much and is difficult to estimate the infected field precisely in wide area. So there is increasing need to develop effective, simplified and low cost method using remote sensing and GIS. With this background, we conducted research on development of new method using remote sensing data for evaluation of damage ratio caused by pest and disease in West Java, Indonesia. In our research, hyperspectral data was acquired using a handheld spectroradiometer. The measurement was made just before harvesting of rice. In addition, 4 specialists conducted the eye inspection and collected data on the infection ratio.

In our analysis work, firstly, the first differential of the hyperspectral data was calculated to extract information on the red edge which shows sharp increase of reflectance in between visible and infrared wave lengths. As a result, 2 peaks on the differential curve were found near 720nm. In the same manner, the green edge was analyzed with the result that negative correlation was confirmed between the BLB infection ratio and the first differential value (R2=0.59). Then, judgement about BLB was tried through logistic regression analysis using an indicator of GMRE (Green edge multiplied red edge). The result showed that the judgement about infection by BLB was possible at 5 %significant level. Finally the study to check if GMRE could be applied to wider area was conducted using the RapidEye data. Positive result was obtained using GMRE derived from green band and red edge.

This study result suggests that the method using the green edge and red age is effective for BLB judgement and can be applied to wide area, considering the change of leaf color from green to yellow orange then to off-white white, brown and finally decolored.

Poster

A approach to obtain a guidance directrix for vision-base agricultural vehicle navigation into orange groves

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http://doi.org/10.5281/zenodo.1002345

Background: Vision sensors have been widely used in mobile robot navigation nowadays. Research on autonomous navigation of mobile robots for tree rows following in groves and orchards is rare relative to crop rows. In this paper, a vision navigation subsystem for an autonomous vehicle operating in citrus groves was developed.

Methods: Tree rows were first extracted according to colour difference using a HSV colour transformation. A specific algorithm was applied to remove the noise caused by the weeds on the driving path and the horizontal scanning method was used to detect the boundaries. The boundary lines were detected by the least squares method combined with RANdom Sample Consensus (RANSAC) mechanisms. A guidance directrix was then generated based on these boundary lines.

Results: The average processing time for one image was about 70ms. All offset errors were compared with the reference trajectory obtained by manually selecting from the image. The average MSE offset error from 261 off-line orange grove images was 4.53 pixels with an average orientation offset error of 2.14 degrees. The average MSE offset error from 631 images which were captured from real-time vehicle experiments was 3.1 pixels with an average orientation offset error of 1.95 degrees.

Discussions: The off-line image sequences and real-time processing experiments showed that the algorithm was able to overcome weeds noise problem on the ground, generate the guidance directrix successfully and met real-time processing requirements.

Conclusion: In this paper, a machine vision algorithm to obtain a guidance directrix for an automatic vehicle guidance system is presented. The algorithm could effectively overcome noise problems derived from weeds on the ground. Further research would be interested in improving the applicability of the algorithm under a range of weather and lighting conditions and other kinds of grove and orchard.

Poster

Development of attitude reference system using extended Kalman filter based on ARM and 16445 Isensors

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Background: Modern micro-electromechanical systems (MEMS) technologies provides the moderate-cost and miniaturized solutions for the development of attitude reference system. Using highly integrated inertial measurement units (IMUs) provided by ADI Company, a mini attitude reference system was developed for precise agricultural control and autonomous vehicle.

Methods: The attitude reference system is composed of an ARM processor (STM32F446RC) and ADIS16445 iSensor® which includes triaxial gyroscopes and triaxial accelerometers. The raw sensors data was sampled by STM32F446RC processor through SPI interface. A second order autoregressive (AR) model was developed to model the random draft error of MEMS gyroscopes. By using extended kalman filter (EKF), the sensor fusion algorithm was implemented for the attitude reference system. The AR model was incorporated into the EKF algorithm and the measurement noise covariance was estimated from the AR model, which limited the fine tuning of noise covariance to the process noise covariance only. To verify the performance of the gyroscopes, accelerometers, and the attitude reference system, the tests were carried out on SGT320E three-axis turntable platform and LOVOL TD904 tractor.

Results: Test results showed that the robust performance of gyroscopes and accelerometers could be obtained with stable supply voltage. Typical accuracy of attitude reference system in static was 0.03 degree with max error 0.1 degree, and the typical dynamic accuracy was 0.7 degree with max error 1 degree. The developed mini attitude reference system had good performance on tractor navigation, so as to autonomous vehicle.

Discussions: Environment temperature will affect the performance of micro-electromechanical devices and the zero bias of gyroscopes and accelerometers, which will need to estimate when applying extended kalman filter.

Conclusion: This paper developed a mini attitude reference system with stable performance and high precision which was suitable to applied in precise agricultural machines and its implements.

Poster

Low-altitude remote sensing systems for precision agriculture

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http://doi.org/10.5281/zenodo.1002329

Modern precision agriculture began by mapping crop fields at different scales to support agricultural planning and decision making. With the development of variable-rate technology, precision agriculture focuses more on tactical actions in seeding, fertilizer/chemical application, and irrigation instead of simply mapping the field in the current year for improvement the next year. This is a major difference between remote sensing for precision agriculture and for general earth observation. With the development of aerial- and ground-based variable-rate systems, low-altitude airborne and ground remote sensing systems, rather than satellite systems, provide high-resolution data for prescribed variable-rate operations.

We developed systems for multispectral and thermal imaging on manned agricultural aircraft, ground based on-the-go hyperspectral imaging, and hyperspectral imaging in greenhouse. Unmanned aerial vehicles (UAVs) provide a unique platform for continuous remote sensing of crop fields at very low altitudes, which is advantageous over manned aircraft. Manned aircraft often cannot fly low enough when fine detail is required, and ground systems can take discrete measurements but slowly. Ground based systems are frequently restricted by field conditions.

Herein we describe systems developed for detection of crop stress caused by multiple factors. The issues of system and data calibration are investigated and discussed. Methods and results of crop sensing using these systems are analyzed and compared. UAVs as a special platform are discussed for crop sensing based on our field practices.

Presentation

Thick then thin – a novel approach to reducing plant spacing variability in small-seeded vegetable crops

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The New Zealand Institute for Plant & Food Research Limited

http://doi.org/10.5281/zenodo.891093

Establishment outcomes can be highly variable in of small-seeded vegetable crops, reducing crop value through lower yields and higher product variability. We conducted a proof-of-concept study to explore the potential to achieve targeted plant populations consistently and to reduce variability in plant spacing by sowing additional seed and thinning emerged plants. In one onion crop, replicated plots were sown at half the standard within-row plant spacing (72 mm). Eight weeks after sowing, plant spacing was recorded in each plot, and then thinned using templates that identified plants to be removed based on spacing from the last retained plant (plant distance thinning), or at fixed distances from the start of the plot (fixed distance thinning). Plant-distance thinning treatments reduced within-row spacing variability (coefficient of variation (CV) 75% pre-thinning to 34% post-thinning). The mean spacing (74 mm) was similar to that of the control plots (73 mm; CV 61%). Fixed-distance thinning treatments increased the mean and CV to 115 mm and 84% respectively. A survey of six commercial onion fields showed that they varied significantly in within-row plant spacing variance (< 0.001). Sowing more thickly, and then thinning small-seeded crops like onions shows promise in reducing plant spacing variability, extending the existing use of this approach from crops such as lettuce where automated thinning is being developed. The next consideration is measuring the impact of thinning treatments on yield and variability and considering automated methods for thinning of tightly spaced crops.

Poster

Fabrication of novel paper-based biosensor for diagnosis of drought stress in plants

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http://doi.org/10.5281/zenodo.1002384

Background: Proline, which is drought resistant material, is produced to protect the cell membrane and it is accumulated proportional to drought stress. Therefore, proline measurement is very important because it can be used as an indicator of the degree of drought. In this paper, we describe for fabrication of an enclosed paper-based microfluidic sensor capable of detecting proline in order to diagnose drought stress in plants.

Methods: Proposed sensor is fabricated by wax printing and origami method. The structure of the sensor is a four-layer. All parts of sensor except detection area and load area are designed to be sealed in the wax by using the origami method. And proline is detected by the reaction of proline-ninhydrin and analyzed using colorimetric methods.

Results: The proline-ninhydrin reaction in the paper sensor is optimized at 110℃ for 5 min. Fabricated paper sensor can measure the proline with various concentrations. From experimental results, it can detect at least 50μM. RGB image analysis is used to measure the color change on the sensor according to the concentration of proline. Green color intensity is decreased as proline concentration is increased.

Discussion: Precise measurement of proline requires an optimized design of microfluidic channels. The shape size of the channel, which is an important factor in the design of the sensor, must be appropriately considered for the sensor to be fabricated. In addition, the paper-based biosensor requires in which ninhydrin is uniformly loaded independently in order to reproducibly detect proline.

Conclusion: We describe for the fabrication of novel paper-based biosensor that can be detected drought stress without contamination from outside environment. The proposed paper-based sensor is simply fabricated by wax printing and origami method. It can be detected proline from drought stressed plants.

Acknowledgement: This work was supported by Korea Institute of Planning and Evaluation for Technology in Food, Agriculture, Forestry and Fisheries(IPET) funded by ministry of Agriculture, Food and Rural Affairs(MAFRA)(No.315012-03, No. 714002-07)

Poster

Comparison of vibration reduction rates of agricultural tractors depending on suspension type

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http://doi.org/10.5281/zenodo.1002249

Background: Because of the tough conditions of agricultural tasks, agricultural tractor drivers can be exposed to extreme vibrations easily and continuously. The cabin suspension of a tractor can reduce the vibration effectively. However, in Korean market, the cabin suspension is not commonly implemented to the tractors yet. As a preliminary research for the development of a LSD-based front axle system with intelligent active suspension for 75-kW tractors, the vibration characteristics of three different tractors classified according to cabin suspension type were investigated.

Methods: PZT type accelerometers were used to measure the vibrations on the wheel axis and cabin while three different tractors were driven on a proving ground. Field experiments were conducted under different drive speed and road conditions. The test tractors selected were varied depending on cabin suspension type, such as a simple spring type, an adaptive suspension system, and no suspension. Because the masses and the tires of the tractors are not identical, a change in the vibration reduction rates of the cabins in a response to the input vibration on each of their wheel axes was compared as a performance index.

Results: The tractor with adaptive suspension showed the largest vibration reduction performance. Especially, the vibration around 5 Hz was considerably reduced compared to those obtained with the others. The tractor with suspension showed intermediate performance while the tractor without suspension showed the smallest reduction rate of the vibration.

Discussion: As expected, the cabin suspension largely affected the vibration characteristics of the tractor in terms of amplitude and frequency.

Conclusion: The results would be used as reference for the further study about active cabin suspension system of tractors.

Presentation

Automatic sugar beet thinner equipped with machine vision

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http://doi.org/10.5281/zenodo.893664

Thinning is one of the most tedious and exhaustive operations in row-crop plant cultivation. It is mostly done manually by employing many labours during hot days in summer. In this study, a pneumatic mechanism was developed to automatically root up the redundant plants to provide enough space for the remaining sugar beet plants. The algorithm designed for thinning the sugar beet plants when there is significant overlapping between the adjacent plants. Retaining the single plants untouched was regarded in the algorithm not to diminish the overall yield of the field due to bare spaces. The performance of the machine was investigated at three different levels of forward speeds. Results showed that the best accuracy of the machine in providing the desired thinning distance between the remaining crops was gained at the speed of 2 and 3.5 km/hr. The machine also achieved well in leaving the single plants untouched with an accuracy of 99.1% while the speed did not have a significant influence on this achievement. Both laboratory and field experiments showed a reasonable performance which encourages the use of automatic thinning for sugar beet cultivation.

Presentation

Determination of establish point of sugar beet plant for use in automatic thinning machine

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Even in the most modern machines, thinning of the crops is done by considering the distance between the crops while they are not accurate enough to detect the exact location of the plant. Detecting the establish point of the plant is one of the main requisites for autonomous thinning and weeding machines. In this study, it was tried to determine the establish point of the sugar beet plant through different approaches. The performance of the algorithms was then verified based on the difference in estimation of a establish point with the actual location of the point. Results showed that

All three algorithms were able to determine the establish point at early growth stage with an acceptable tolerance respect to the actual location. Evaluation of the methods for determining the establish point of the sugar beet showed that when sugar beet plants were small and in a range of 3 to 5 leaves, the Hough approach was preferable while in later growth stages up to 8 leaves, centroid and regression approach could produce a better result while variation of the plant shape and residual noises in the image has the lowest influence on the performance of the Hough method.

Keywords: Precision agriculture, machine vision, image processing, weeding robot

Poster

Severity analysis of 75kW agricultural tractor PTO gear using a field data

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Background: Agricultural tractor is the agricultural machinery which conducts several operations using various implements such as harvester, baler and trailer. Power from the engine is directly transmitted to driving shafts and PTO (Power Take Off) shaft. Power delivered to PTO shaft is transmitted to the implements through the PTO gear. The gears are components of transmission which transmit the power of an engine to a machine and offers various speed ratios, a compact structure and high efficiency of power transmission. A gear train design in the automotive industry uses simulation software. However, the PTO gear design for agricultural applications uses the empirical method because of the wide range of load fluctuations in agricultural fields.

Methods: Therefore, severity analysis with agricultural operation of PTO gear using a simulation is essential to the optimal design of the PTO gear. In this study, severity analysis using a simulation proceeded in full load condition and real work condition (70% rotary tillage, 30% baler operation) during the rotary tillage, baler operation.

Results: Simulation results showed the severity of full load condition was the higher than the real work condition.

Discussion: This study secured the reliability of the PTO gear design through the severity analysis, and it also proved the feasibility of implementation of the optimal design by using gear analysis software.

Conclusion: Thus, it is necessary to design the tractor PTO gear in consideration of the field data.

Poster

Estimation of moisture content in cucurbitaceae seedlings using hyperspectral imagery

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http://doi.org/10.5281/zenodo.1002255

Background: This research was conducted to develop moisture content model and estimate its performance in cucurbitaceae seedlings, such as cucumber and water melon, using hyperspectral imagery.

Methods: Using a hyperspectral image acquisition system, reflectance of leaf area of cucumber (n=45) and watermelon (n=45) seedlings was calculated after providing water stress. Then, moisture content in each seedling was measured by using a dry oven. Finally, the moisture content estimation models were developed by PLS-Regression analysis with reflectance data and moisture content data.

Results: After developing the estimation models, the cucumber model predicts that performance is significant as 0.73 of R2, 1.45% of RMSE, and 1.58% of RE. The watermelon model predicts that performance is acceptable as 0.66 of R2, 1.06% of RMSE, and 1.14% of RE. The model performed slightly better after removing one sample from cucumber seedlings as outlier and unnecessary. Hence, the performance of new model for cucumber seedlings (n=44) showed 0.79 of R2, 1.10% of RMSE, and 1.20% of RE. The model performance combined with all samples (n=89) showed 0.67 of R2, 1.26% of RMSE, and 1.36% of RE.

Discussion: The model of cucumber showed better performance than the model of water melon. This is because variables of cucumber are consisted of widely distributed variation, and it affected the performance. Further, accuracy and precision of the cucumber model were increased when an insignificant sample was eliminated from the dataset. Finally, it is considered that both models can be significantly used to estimate moisture content, as gradients of trend line are almost same and intersected.

Conclusion: It is considered that the accuracy and precision of the estimating models possibly can be improved, if the models are constructed by using variables with widely distributed variation. The improved models will be utilized as the basis for developing low-priced sensors.

Presentation

Monitoring the growth status variability in Onion (*Allium cepa*) and Garlic (*Allium sativum*) with RGB and multi-spectral UAV remote sensing imagery

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http://doi.org/10.5281/zenodo.895363

Traditional ways of monitoring the growth status of crops in the early and middle seasons rely on manual methods involving sampling and laboratory analysis, which are time-consuming and costly. In addition, a diagnostic method based on human eyes has a limitation in identifying invisible symptoms of crops with internal defects. Since UAV remote sensing allows fast and detailed mapping of crop growth due to the ability to obtain high-resolution images flying at low altitudes, an UAV platform is appropriate for collecting the images of onion and garlic vegetables with relatively small leaf areas in the early season. In this study, an experimental plot was prepared growing garlics and onions based on different planting timings and fertilizer rates, and the RGB and Multi-spectral UAV images of the onions and garlics on a spatial resolution of < 1 cm were collected to build relationships between the UAV images and various biophysical parameters of garlic and onion. Two spectral indices, i.e., vegetation fraction and 3D-based height estimation, obtained with a RGB camera were used to estimate the fresh weights of garlic and onion, and the nutritional status of the crops was studied based on NDVIs calculated using multi-spectral imagery obtained with a multi-spectral camera in order to investigate the potential for variable-rate fertilizer application. Image pre-processing techniques and crop segmentation methods for effectively extracting the images of garlic and onion were developed. The multi-linear regression models to estimate the average fresh weights of onions and garlics built based on RGB images showed the coefficients of determination>0.9 and >0.7 for onion and garlic, respectively. However, there was little effect of fertilizer application rates on the NDVIs in the early stage.

Poster

How can we demonstrate the economic value of Precision Agriculture (PA) practices to New Zealand agriculture service providers and arable farmers?

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http://doi.org/10.5281/zenodo.1002380

- The amount of data collected has become a major challenge to the uptake of PA practices in New Zealand.
- There is a lack of clear value propositions around some PA practices, e.g. variable rate seeding (VRS).
- The importance of calibrating yield monitors, collecting yield data and mapping results has not been realised by farmers.

The goal of the study is to provide economic evidence through yield data mining to encourage the adoption of PA.

Poster

On-the-go image processing system for real-time measurement of plant growth status

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http://doi.org/10.5281/zenodo.1002349

Background: For identifying the best growth conditions for plants, plant feature measurements is an important and commonly used indicator. Traditional plant feature measurements are destructive and laborious. In our previous study, an automatic system based on image-processing was developed, which could measure the features of plants non-destructively. However, the system is could not provide real-time information about individual plants due to its use of post image-processing. To enhance the practical use of the developed system, in this study, an on-the-go image acquisition and processing system was developed.

Methods: This system included an image measurement system and a real time image processing system. The image measurement system consisted of stepping motors, linear actuators and a real-time transmission camera. The stepping motor drove the linear actuators to move the camera on a constant distance based on Cartesian Coordinates. The real time image processing algorithm was programmed in MATLAB. The developed system was installed in plant factory, where lettuces were grown based on the ebb and flow method to estimate the fresh weight of individual lettuces in real-time using the image of leaf area for each lettuce obtained with RGB camera.

Results: The experimental testing showed that it was possible to measure the fresh weight of each lettuce in real-time with a satisfactory level of accuracy as compared to those obtained from the previous post processing-based system.

Discussions: There were some limitations in measuring the leaves over lapped by showing a difficulty in segmenting leaf images for individual lettuce. In future studies, different image processing methods such as the Object Based Image Analysis (OBIA) will be used to improve the system performance.

Conclusion: The experimental results demonstrated the satisfactory performance of the developed system. It was expected that the developed system would be a useful tool for precision management of plant grown in plant factory.

Poster

An improved method of interpolating annual crop yield data using wavelet transform

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Background: Annual crop yield data is a typical time series data in Precision Agriculture. Most data is constituted by some observations at irregularly scattered points in time due to the finite cost of data acquisition and its difficulties, so the data is corresponding to a subset of the whole study period. In this study, we aim to present an improved interpolation method for the annual crop yield data by introducing wavelet filtering to auto-regressive integrated moving average (ARIMA) model.

Methods: With the proposed method, wavelet transforms were conducted to decompose the original time series data into approximation coefficient and detail coefficients, and each coefficient was fitted by ARIMA model. Then, the interpolated data was obtained by re-aggregating the fitted approximation coefficient and detail coefficients, and a cross-validation was applied to evaluate the interpolating accuracy.

Results: In the experiment, annual wheat yield data got from 27 agrometeorological stations distributed throughout main winter wheat producing areas of China over a 30-year period (1981 to 2010) was used to evaluate the proposed method. The results showed that the proposed method yielded more accurate results than conventional ARIMA and linear interpolation. Moreover, the proposed method is not sensitive to the length of the time series, because the wavelets have the advantage of handling multi scale features of the original data.

Discussions: Besides the greater interpolation accuracy, the proposed method concerns of multi-scale feature of the time series data, and brings about multi-scale decomposition of the data, which will reveal more inherent information of the data.

Conclusion: The method introduced in this paper increases the accuracy of annual crop yield data interpolation, and also will be an effective method of analysing the data.

Poster

An electrically driven, computer controlled robotics platform for orchard use

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As automation in agriculture progresses, more automation systems will be placed into farms & orchards.

Systems that service the crops directly are likely to have positioning requirements that make traditional tractor-trailer units unsuitable.

This paper introduces a platform built for transporting robotics modules through a kiwifruit orchard.

Performance figures, design considerations and a general hardware overview are presented.

The platform is controlled either by remote or computer generated drive commands - facilitating autonomous navigation.

In-orchard testing shows the system is well suited for the target application, achieving stable speed control and repeatable positioning.

Poster

Estimation of the moisture content in Solanaceae seedlings using hyperspectral image

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http://doi.org/10.5281/zenodo.1002351

Background: This research was performed to develop moisture content model for solanaceae seedlings, such as chili pepper and tomato, based on hyperspectral imagery.

Methods: After exposing to high temperature, the reflectance of chili (n=45) and tomato (n=45) seedlings were calculated using the hyperspectral imagery, and the moisture content of all seedlings was measured. Then the predicting models for estimating moisture content were developed with PLS Regression analysis by using the two factors

Results: As a result, the chilli model showed 0.68 of R2, 1.43% of RMSE and 1.61% of RE, which indicate accuracy and precision respectively. The tomato model showed 0.74 of R2 2.77% of RMSE and 3.09% of RE. Combining all samples (n=90), the solanaceae model showed 0.67 of R2 2.53% of RMSE and 1.61% of RE. Finally the full-cross validation showed 0.59 of R2, 2.83% RMSE and 3.17% of RE.

Discussions: Accuracy and precision of the tomato model was slightly better than those of the chilli model. This might be affected by widely distributed variation in tomato seedlings. The solanaceae model, which is combined with chilli and tomato, showed lower accuracy than each single model, however, the precision was higher than the tomato model. This is because that tomato samples distribution was located in chilli distribution and this affected the performance better. Finally, it is considered that both models can be significantly used to estimate moisture content, as gradients of trend line are almost same and intersected.

Conclusion: It is considered that the accuracy and precision of the estimated models possibly can be improved, if samples are under a lot of stress. The improved models will be utilized as the basis for developing low-priced sensors.

Poster

Evaluation of subsurface irrigation system based sensing soil moisture for soybean *(Glycine max* L.)

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http://doi.org/10.5281/zenodo.1002323

Background: Water management has become the most indispensable factor for augmenting the crop productivity especially on soybean because of their high susceptibility to both water stress and water logging at various growth stages. The objective of this study was to determine the possible effect by automatic irrigation systems based on soil moisture on soybean growth.

Methods: The study had three different irrigation methods as sprinkle irrigation (SI), surface drip irrigation (SOI) and fountain irrigation (FI). Sl was laid down in 7x7m interval as square for per irrigation plot, SOl a lateral pipe was laid down to 1.2 m row spacing with 2.3 L h-1 discharge rate, the distance between laterals is 20 cm spacing between drippers and Fl was laid down in 3m interval as square for per irrigation plot. Soybean (Daewon) cultivar was sown in the June 20th 2016, planted in 2 rows of apart in 1.2 m wide rows and distance between hills was 20 cm.

Results: This automatic irrigation system uses valves to turn irrigation easily automated by using controller, solenoids and moisture sensor in adjusting available soil moisture levels 30% at 10cm depth. Irrigation application efficiency is obtained by dividing the total water stored in the effective root zone on the applied irrigation water. Seasonal applied irrigation water amounts ranged from 60.4 ton 10a-1 (SI) to 47.3 ton 10a-1 (SOl) and from, 92.6 ton 10a-1 (FI), respectively.

Discussions: The most significant advantage of SOl system was that water is supplied near the root zone of the plants drip by drip due to which a large quantity of water was saved 27.5% and 95.6% compared to Sl, Fl system.

Conclusion: It could be concluded that improving automatic irrigation system can contribute greatly to reducing production costs of crops, making the industry more competitive and sustainable.

Poster

Machine vision based system for flower counting in strawberry plants

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http://doi.org/10.5281/zenodo.1002347

Background: For strawberry production, accurate yield prediction is very important to help growers increase their profit by efficiently managing their harvesting operation and setting their contracts with buyers. Strawberry plants produce flowers and fruits simultaneously throughout the season. Strawberry flowers are white in color with a yellow pollen at the center, which later becomes a fruit. Strawberry yield can be estimated by counting the number of flowers in a field in advance of harvesting. The objective of this project is to count the number of flowers using image processing techniques, create a map of flower counts using gee-tagging and provide farmers with an estimate of the yield in a given area.

Methods: Strawberry flowers could be at different stages of maturation during imaging. We pre-process images using edge-preserving smoothing filter to remove noise without removing fine features. The next stage involves segmentation of flowers from the background. Since flowers are brighter than most other components of plants, simple thresholding with segmentation algorithm will produce candidate pixels. Then flower detection will be conducted using traditional feature engineering along with a classifier such as Histogram of Oriented Gradients, Wavelet Transform, Local Binary Patterns, and the Deep Learning based techniques.

Results: Once flowers are detected, the number of flowers is counted to provide farmers with an estimate of yield and variability at different locations in the field.

Discussions: One of the biggest challenges with outdoor imaging is the variable lighting conditions. We propose a camera mounted autonomous system to go over rows of strawberry plants to capture images with geo-tags. Cameras are positioned to capture images from different angles to capture occluded flowers.

Conclusion: A novel image processing method for accurate strawberry yield prediction is proposed by counting the number of flowers from images for efficient crop management.

Poster

Development of a test bench for drip irrigation electronic valve

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Background: Efficiency of a water management and irrigation control system is important for improved production and quality of crops. Electronic valve is one of the most important components for the irrigation management system, and the performance is characterized by the flow-pressure relationships. In the study, a test bench was developed to test electronic valves for irrigation management systems.

Methods: A multistage pump (Model: DRL10-8; DOOCH, Korea), flow rate sensors (Model: E-MAG-I, AUTOFLOW, Korea), and pressure sensors (Model: A-10; WIKA, Germany) were used to construct the test bench. A control program was coded to control the pump operation. The flow rate was set at four different levels (20, 40, 60, 80 m3/h) using the multistage pump. Flow rate and pressure sensors were installed before and after the test electric valve. Data were collected through a wireless sensor network. The electric valve was controlled remotely by the software developed using C # (visual studio 2010, USA).

Results& discussion: The experimental results showed that the error ranges were 2% at 20 m3/h and 7% at 80 m3/h. We found that the flow rate within 20 ~ 80 m3/h and the pressure loss within 2 ~ 10 bar measured before and after the electric valve were linearly plotted. The pressure decreased 10% before and after the solenoid valve. The delay time need to be considered for stable flow control. To solve this problem, relief valve was installed to remove the flow rate exceeding the specified value.

Conclusion: The test bench should a favourable performance, and will be used to test and compare electronic valves.

Poster

Modeling the growth of Chinese cabbage using remote sensing system

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http://doi.org/10.5281/zenodo.1002357

Background: Chinese cabbage of the typical crop in Asia is crucial source of supply containing abundant fibroid materials, minerals. It is required to forecast and diagnose growth by remote sensing (RS), GPS and GIS for precision production management of Chinese cabbage.

The objective of this study was to develop model for estimating the growth (Fresh weight, leaf area) with spectral information of Chinese cabbage in multispectral image acquired by using unmanned aerial system depending on vegetation stages.

Methods: Chinese cabbage in test field was planted on normal planting period (NP) and two delayed planting periods (DP). Multispectral images of test field were acquired at intervals of 2 weeks in midday by using NIR and red edge camera mounted on UAV. Vegetation index and band ratio was calculated by spectral information of sample extracted by image processing. Simple linear regression analysis was employed to develop model of relationship between the growth and index, ratio.

Results: It was developed to two models for accurately estimating the growth because models between NP and DP show different linearity in all vegetation stage. The model using NDVI calculated by NIR and Red bands exhibited lower performance (R2=0.690 and RMSE=868.4g in NP, R2=0.851 and RMSE=285.1g in DP) by saturation of light-sensitivity NIR. The model using ratio between less light-sensitivity Red edge and blue bands in NP exhibited the best performance (R2=0.798, RMSE=700.9g). Also, the models using ratio between Red edge and green bands in DP exhibited the best performance (R2=0.951, RMSE=162.4).

Discussions: It is regarded that red edge band has to be used to solve the problem because it was revealed that light-sensitive NIR band is easy to be saturated at intermediate to high weight.

Conclusion: It was possible to accurately estimate the growth of Chinese cabbage with ratio of red edge and visible bands depending on vegetation stages.

Presentation

Characterizing the spatial variability of soil properties and crop yield using high-resolution remote sensing image and ground-based data

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2 Farm Science Review, Ohio State University
http://doi.org/10.5281/zenodo.895477

Site-specific management practices offer a strategy to optimize agronomic inputs if the causes for spatial and temporal variability in crop yield are understood, and can be related to one or more field properties. The objectives of this study are to: (i) determine the suitable methodology for predicting soil properties and crop yield at high-spatial-resolution by evaluating various machine-learning algorithms, and (ii) identify the relationships between crop yield, soil and topographic properties. The analyses will be based on four soil properties (soil organic carbon, potassium, soil cation exchange capacity and magnesium), and maize (*Zea mays* L.) yield data from a maize-soybean (*Glycine max*) rotation field in central Ohio, USA. Topographic properties including slope, aspect, roughness, terrain ruggedness index, topographic position index, and flow direction were derived from a high-spatial-resolution (1 m) digital elevation model data. Soil and vegetation indices were derived from a high-spatial-resolution (0.30 m) multispectral bare-soil aerial image. Soil properties were estimated at high-spatial-resolution by integrating field-collected soil samples, topographic properties, and spectral information (individual spectral bands and indices) derived from multispectral aerial image. Continuous maize yield estimates were then predicted by integrating aforementioned data. Multiple linear regression (LM) and two machine-learning algorithms, including random forest (RF) and neural network (NN), were investigated to evaluate and identify the method that best characterized the relationships between bare-soil multispectral image, soil properties and crop yield. Comparison of models for estimating soil properties and crop yield demonstrated that soil organic carbon and crop yield can be predicted using bare-soil multispectral image with higher accuracy using the RF model. The LM model predicted soil cation exchange capacity and magnesium with higher accuracy, and NN performed better in estimating potassium. Based on the analyses of importance of variables across the three models for maize yield prediction, variables including red and green spectral bands, and soil indices derived from bare-soil multispectral image, and cation exchange capacity were found to be the five most significant predictors influencing maize yield estimates.

Keywords: Remote sensing, Yield, Variability, Soil, Topography

Presentation

Development of real-time onion disease monitoring system using machine vision

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http://doi.org/10.5281/zenodo.895371

Background: To provide optimum environmental condition agricultural crops, it is necessary to environmental monitoring of continuous crops. Especially, it needs to minimize that effect of crops to disease manifestation by real-time monitoring. Therefore, the purpose is development of machine vision system for disease monitoring of crops.

Methods: In this study, machine vision system consisted of infrared floodlight camera, servo motor and lifting device. The infrared floodlight camera contains intelligent video analytic function, automatic sound alarm, after recorded image function. In addition, this camera designed that enable to rotate 360 degrees for monitoring all around environment. Servo motor system is installed stand for position controller. Lifting device is available for moving the camera up and down.

Results & Discussions: Image of crops was difference between disease crops and without disease crops. Therefore, it is possible to detection disease using a machine vision system. The results of this study showed that developed environment monitoring system using machine vision is feasible as real-time measurement by measurement condition such as day/night, and measuring point.

Poster

Data collection for analysis of productivity improvement of plums using remote data collection device made by general purpose single-board computer

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http://doi.org/10.5281/zenodo.1002888

General-purpose single-board computers such as Raspberry pi help to develop IoT-based remote monitoring device cheaply and easily, so it is highly utilized to collect data on growing environment and cultivation history of plums for small and medium scale plum farms.

We have developed a remote sensing and data acquisition system using these small single-board computer at a basic stage to analyze the environmental and growth factors that can affect the productivity of plums.

The first prototype used the Arduino MKR1000 to fabricate a data acquisition and transmission module and configured the system using a cloud storage called IoT Makers operated by KT, South Korea's largest telephone company. In order to assess advantages and disadvantages of the data collection device using MKR1000, we conducted an indoor test at the Industrial Machinery Lab at Suncheon National University in 2016. Currently, we are developing a device that uses Raspberry pi as a data acquisition and transmission module.

The final data collection system will be installed in the plum field near Suncheon in 2017 and the actual sensing data will be collected. The collected data will be used to analyze factors related to the improvement of plum productivity.

Remote data collection using low-cost, general-purpose IoT devices will provide the possibility to discover factors related to productivity of various crops as well as plums with low cost and effort.

Poster

Basic tests of potato yield monitoring sensors for small-sized Korean harvesters

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http://doi.org/10.5281/zenodo.1002372

Background: Mechanization rate of dryland crop production in Korea is about 56%, and especially the rate is very low (13.3%) for harvesting operation. Recently, precision agriculture technologies including real-time yield monitoring sensors are in demand by female and aged farmers for user comfort. Purpose of the study was to conduct basic tests of yield monitoring sensors for small-sized Korean potato harvesters.

Methods: Candidate sensing modules were selected for mass flow (i.e., load cell) and volume flow (i.e., CCD camera) measurements on the way of potato transportation from the digging part to the collection part. Laboratory test bench was constructed using a commercial potato harvester available in Korea, and the sensing modules were instrumented at the end of the transportation part. Calibration tests were conducted with sample potatoes. Effects of speed of the transportation part, distance between the transportation part and sensing module, vibration and slope of the test body were investigated.

Results and discussions: Calibration tests of the mass flow sensor provided fairly good results with R2 of 0.95 and RMSE of 11 g. The performance of the mass flow sensor was significantly affected by the number of load cell, and vibration and slope of the test body. The volume-based sensor also showed good results with R2 of 0.91 and RMSE of 12 g. The performance was significantly affected by the vibration and slope of the test body. Effects of the speed of the transportation part, and distance between the transportation part and sensing module were not statistically significant within the tested conditions.

Conclusion: Both of the mass flow and volume flow approaches showed promising results. Further tests should be conducted to minimize the effects of vibration and slope of the test body, especially considering the harvesting field conditions.

Poster

Analysis of load severeness for the transplanter PTO by planting condition

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http://doi.org/10.5281/zenodo.1002386

Background: Analysis of load on the transplanter PTO shaft is critical for optimum design of a transplanter. The purpose of this study was to analyze the load severeness of the transplanter PTO shaft during field operation by planting condition.

Methods: In order to measure the loads acting on the PTO shaft of transplanter, a load measurement system was installed on the transplanter. A load measurement system was constructed with torque sensors to measure the torque of a PTO shaft, a measurement device to acquire sensor signals, and embedded system to calculate the load severeness. Field operation was conducted at four planting distances (26, 35, 43, and 80 cm) and three planting depths (level 1, 5 and 10) on a field with similar soil conditions. The load data was converted to a load spectrum using the rain-flow counting method and SWT (Smith Watson Topper) equations. Sum of damage due to the load was calculated using the Modified Miner's rule for each planting conditions, and then the load severeness was calculated as the relative magnitude of the damage sum.

Results: The average torque on the PTO shaft increased significantly as the planting distance decreased from 80 cm to 26 cm. Also, the average torque on the PTO shaft increased as the planting depth increased from level planting depth level 1 to 10. The severeness of the load on the PTO shaft increased as planting distance decreased and planting depth increased.

Discussion: Farmers should determine the planting conditions of the transplanter by considering load and durability of machine.

Conclusion: The results of this study provide useful information for the optimum design of a transplanter PTO considering field load. In addition, future studies need to provide basic data for the design of the transplanter by considering the working speed and various work conditions.

Poster

Estimation of the growth for radish and Chinese cabbage using hyperspectral image

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http://doi.org/10.5281/zenodo.1002361

Background: Hyperspectral camera is useful for finding a wavelength range that can estimate growth by using wide spectrum (400-1000nm) ranges. It is possible to apply precision agriculture through determination of accurate harvest season, amount of applied fertilizer and so on according to estimation of growth. The objective of this study was to estimate the growth for radish by using hyperspectral image depending on vegetation stages.

Methods: Hyperspectral images of Radish and Chinese cabbage were acquired at intervals of 2 weeks in midday. It was divided into the crop and background area in image by using NDVI and the reflectance values of crop area were calibrated by the values of reference board in same image. PLSR analysis was employed to develop model for estimating growth of the crops with the all spectral band of all vegetation stages. The models for estimating the weight of the crops were evaluated through R 2 and root mean square error (RMSE), which were verified as validation model by full-cross validation.

Results: The model for estimating the fresh weight for Radish exhibited high performance (R2=0.950, RMSE=236.3g), but validation model exhibited high error value (R2=0.806, RMSE=492.3g). Likewise, the model for estimating the dry weight exhibited high performance (R2=0.975, RMSE=3.413g), but validation model exhibited high RMSE (R2=0.843, RMSE=8.993g). The model for estimating the fresh weight for Chinese cabbage exhibited high R2 (R2=0.897, RMSE=571.1g), but estimation and validation model exhibited high error value (R2=0.859, RMSE=685.0g).

Discussions: The estimation and validation model of the fresh and dry weight for the crops are required to improve RMSE by using different statistics analysis and various vegetation indices. Also, comparative analysis between spectral attributes of this experiment and repeated experiment are required.

Conclusion: It is possible to mostly estimate growth of the crops, but estimation and validation models of weight are needed to improve RMSE.

Poster

Relationships between crop yield and landscape features

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http://doi.org/10.5281/zenodo.1002291

Background: Sound agronomic recommendations are crucial for today's agronomists as they strive for improved yields, profits, and sustainability. Determining the spatial relationships between yield and landscape variation including soil properties, soil texture, and terrain attributes may improve management decisions, particularly with regards to proper nitrogen application for minimizing both costs to farmers and environmental impacts.

Methods: Here we investigate relationships between landscape features and corn yield as part of a preliminary study to model corn yield with variations in landscape attributes, soil properties, and weather. We used yield monitor data collected from 2010- 2015 at a 12 ha field at the Davis Purdue University Agricultural Research Center in Randolph County, IN, USA We obtained 15 digital elevation-based models of terrain attributes that describe morphometric and hydrologic characteristics of the field. For each year we used the random forest method to select terrain attributes that were most important for predicting corn yield across the field. We performed cluster analysis with these variables to select the terrain attributes for our spatial regression models. Models, either the spatial error or the spatial lag model, were selected based on the lowest Akaike Information Criterion (AIC) score for the model.

Results: The most important terrain attributes for predicting corn yield were topographic wetness index, topographic position index, relative slope position, catchment slope, and catchment area.

Discussions: These results demonstrate that models for predicting corn yield in Indiana need to include landscape features for increased model performance.

Conclusion: This analysis met one objective of a larger investigation that will incorporate soil properties, soil texture, and weather patterns into models of corn yield across Indiana landscapes.

Poster

Multiple local calibration modeling using a tractor-mounted soil analyzing system

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http://doi.org/10.5281/zenodo.1002223

Background: In precision agriculture, rapid, non-destructive, cost-effective and convenient soil analysis techniques are needed for soil management, crop quality control using fertilizer, manure and compost, and variable-rate input for soil variability in a field. Visible and near-infrared spectroscopy is an effective measurement method for estimating multiple soil properties at once.

Methods: The experimental site is a commercial paddy field in Ibaraki Prefectural Government, Japan. The experiment was conducted on 5 fields (6.4ha) after harvesting for development of multiple local calibration models (MLCM). To develop MLCM, soil samples were collected a total of 100 soil samples from the corresponding scanning positions of Vis-NIR data using Tractor-mounted soil analysing system (SAS). Partial least-squares regression coupled with leave-one-out cross-validation method were used to establish the relationship between Vis-NIR underground soil reflectance spectra captured by SAS and MLCM were obtained through soil analysis. To develop MLCM, the Unscrambler V9.8 software was used. We show coefficient of determination (R2) and residual prediction deviation (RPD).

Results: We obtained MLCM based on Vis-NIR underground soil reflectance spectra collected using SAS. The investigated soil properties were moisture content, soil organic matter, pH, electrical conductivity, cation exchange capacity, total carbon, ammonium nitrogen, hot water exchangeable nitrogen, nitrate nitrogen, total nitrogen, exchangeable potassium, exchangeable calcium, exchangeable magnesium, hot water soluble soil boron, soluble copper, exchangeable manganese, soluble zinc, available phosphate, C/N ratio, MgO/K20 ratio, CaO/MgO ratio, lime saturation degree, base saturation degree, phosphate absorption coefficient, exchange acidity, free iron oxide, sodium oxide, available silicate, bulk density, sand, silt and clay. The accuracy of MLCM on leave-one-out cross-validation method was obtained R2 from 0.70 to 0.92 and RPD form 1.81 to 3.61.

Discussion & conclusion: To get good local calibration model of Exchange acidity, sodium oxide and soluble zinc require addition of new sample data and reanalysis.

Presentation

Mobile device machine vision estimation of mango crop load

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http://doi.org/10.5281/zenodo.895382

The application of machine vision in orchard was considered in context of mango crop load (fruit number and fruit size). An algorithm for automatic detection and counting of fruits in images of trees in orchard was developed. RGB images were acquired of two sides of mango trees ('dual view'). Fruit count per tree was obtained by harvest of trees, and by manual count of fruit in images. The R2 and slope between dual-view and harvest count varied between 0.74 and 0.92, and 0.34 and 0.55, respectively, depending on canopy structure. The fruit counting model involved: (i) fruit-like object detection using HAAR cascade classifier using an AdaBoost technique; (ii) classification of detected region using a multilayer Convolutional Neural Network (CNN). The machine vision count achieved a precision = 0.94, recall= 0.89, and F1 score = 0.9 against a human count of fruit in images. For the estimation of fruit size individual fruits were imaged against a backing board (with a circular scale printed on a blue background), with an RMSE of 3.6 mm for lineal dimension measurement achieved.

Presentation

GIS based site specific major nutrient maps and recommendations for coconut gardens

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http://doi.org/10.5281/zenodo.890227

Spatial distribution of nitrogen, phosphorus and potassium were studied from 99 coconut farmers covering 195 acres representing different irrigation situations in Chikkapattanagere of Chikkamagaluru district, Doddaghatta of Davangere district, Siriyur of Shivamogga district and Madhure of Chitradurga district of Karnataka state, India. The gardens selected were aged 20-25 years with varying management levels. Standard technique of grid method of sampling at 50x50 m spacing was employed to collect soil samples from selected study area at two depths (0-30 and 30-60 cm) with geographical identity by GPS. The soil samples were analysed for major nutrients by following standard procedure. Across all locations nitrogen status remained low while that of phosphorus shared medium to high status in equal proportion. With respect to potassium, 68 per cent of the top soil had high status. Using these data on GIS environment, fertility mapping of each area was done. Fertilizer recommendations based on soil test values for each grid is employed to calculate major nutrients requirement for fertilizer application. The package recommendation and the site specific recommendation are compared. Rescheduling of major nutrients based on site specific variations of 0-30 cm emphasized slightly higher application (844 kg) of nitrogen and marginally less application of phosphorus and potassium. Study reveals the variations in application of nutrients providing scope for re-allocation of these resources based on site specificity. Depending on site specific nutrient variations, nutrient application advisories were recommended for farmers in each location.

Presentation

Current status and future trends of precision agricultural aviation technologies

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http://doi.org/10.5281/zenodo.998941

Modern technologies and information tools can be used to maximize agricultural aviation productivity allowing for precision application of agrochemical products. This paper reviews and summarizes the state-of-the-art in precision agricultural aviation technology highlighting remote sensing, aerial spraying and ground verification technologies. Further, the authors forecast the future of precision agricultural aviation technology with key development directions in precision agricultural aviation technologies, such as real-time image processing, variable-rate spraying, multi-sensor data fusion and RTK differential positioning, and other supporting technologies for UAV-based aerial spraying. This review is expected to provide references for peers by summarizing the history and achievements, and encourage further development of precision agricultural aviation technologies

Keywords: precision agricultural aviation technology, remote sensing, aerial spraying, ground verification

Poster

Fatigue life prediction of PTO gears for a small multi-purpose cultivator by ditching rotor operation

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http://doi.org/10.5281/zenodo.1002862

Background: Rural labor force in Korea has recently been steadily decreased of population and increasing of aging population. Therefore, small multi-purpose cultivator is widely used for field operation due to the field of small scale in Korea.

Methods: This paper measured and analyzed the engine torque of the cultivator by ditching rotor operation, and then fatigue life prediction of PTO gears for a small multi-purpose cultivator using the ISO 6336 and Miner's rule. The torque measurement system was constructed with torque sensors to measure the torque of a engine shaft, a measurement device to acquire sensor signals. Conditions of field test were conducted at two transmission gear stage (1st, 2nd) and two PTO gear stage (1st, 2nd) with 100 mm working depth on the field with similar soil conditions.

Results: The average torques on the engine shaft for PTO gear 1st, 2nd at transmission gear 1st were 11.64, 18.05 Nm, respectively; the same for PTO gear 1st, 2nd at transmission gear 2nd were 17.67, 22.98 Nm, respectively**.**

Discussion: As gear selection is higher, the torque on engine shaft tended to increase and the fatigue life of PTO gears are reduced.

Conclusion: Therefore, farmers should carefully determine the gear selection of the cultivator by considering the load and durability of the machine.

Poster

Effect of subsurface irrigation systems on water use efficiency and soybean growth

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http://doi.org/10.5281/zenodo.1002227

Background: Water stress during the critical growth periods reduces crop yield and quality. The present study was evaluated the effect of subsurface irrigation systems on water use efficiency and soybean growth at sandy-loam soil.

Methods: Tractor attachable dripline injector was used to install the dripline to the each plot at NICS research field in Miryang, Korea. Five irrigation treatments including the control were applied in response to application wide (70 and 140cm) and position (under ridge and furrow). Each plot contained twelve crop rows, 38m in length and 70cm row spacing.

Results: Soil water content at top 10cm was significantly greater than the control, which was significantly increased to 15.8% with 70cm interval under ridge, 19.1% with 70cm interval under furrow, 21.0% with 140cm interval under ridge, and 24.6% with 140cm interval under furrow, respectively. Soybean yield components including plant height and stem thickness were strongly influenced by irrigation practices. Chlorophyll concentration was also greater with irrigation practice compared to the control in whole growth stages. The highest grain yield was 3.35 ton/ha with 70cm interval under ridge plot, which was 34% more yield compared to the control.

Discussion: Soybean yield components and grain yield were significantly influenced by irrigation practices due to the plant favourable soil management such as timely water supply. The design of subsurface irrigation system has different water use efficiency during the soybean growth periods.

Conclusion: The results of this study indicate that the subsurface irrigation system is one of the best management options for soybean cultivation in sandy-loam soil. Although soybean would not be considered a typical crop for subsurface irrigation in Korea, the some advantages including yield increase can be a large counterbalance against the extra irrigation cost.

Poster

Groundwater management system on soil characteristics and soybean growth at paddy field

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http://doi.org/10.5281/zenodo.1002231

Background: Field crop production at paddy field is great concern due to the declining of rice consumption and low crop self-sufficiency ratio in Korea. Groundwater management system will make optimal soil conditions and crop growth possible. The present study was evaluated the effect of groundwater management practice on soil characteristics including soil water distribution and soybean growth at paddy field.

Methods: Groundwater management system was installed with two drain spacing (3m & 6m) at silt loam field at the experimental station in National Institute of Crop Science, Korea. It was managed with two ground water level (0.3m & 0.6m) during the growing season.

Results: The depth of groundwater table was significantly influenced on drainage amount from the soil profile through the drains. Soil water content, electrical conductivity and plant available nitrogen content in soil was significantly greater with 0.3m water table management plot compared to 0.6m plot and the control. At the vegetative stage chlorophyll concentration was significantly lower with higher water table control, but it was recovered at the post-flowering stage. Soybean yield was increased with groundwater management system and soybean yield with 6M drain spacing and 0.6m water table level was 3.38 ton/ha, which was 50% greater compared to the control.

Discussions: Groundwater management system directly influenced on drainage amounts, which significantly delayed the infiltration rate and nutrient loss. These results are comparable to other researches, which reported that the reductions of drain flow and nutrient loss are the major mechanism to better crop development.

Conclusion: The results of this study indicate that groundwater management system can influence on soil characteristics and it is an important practice of high yielding soybean production at paddy field, which should be considered crop development stages for stable crop production.

Poster

Design and construction of an automatic white-fly collecting device control system for smart greenhouse

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Background: Recently, the rapid increase in facility cultivation area provided good conditions for wintering and breeding of whitefly. It has a tendency to increase the damage caused by whitefly every year. Therefore, remote control technology for whitefly reduction is in urgent need. Chemical use to control diseases and insects is 56.7 %, and this is the cause of severe environmental pollution. An automatic white-fly collecting device is under development. In the study, a remote control system was designed and constructed for the collecting device.

Methods: The white-fly collecting device is composed of a rail-moving motor, a fan-blower, an electric wire mesh, and UV lamps. Remote control system was designed and constructed so that the system components were individually controlled. And the status of each component could be monitored. Wireless communication was achieved by the ZigBee module in the greenhouse, and by the smartphone between the greenhouse and users. Performance of the monitoring component was tested by distance and the number of the system component. Overall remote monitoring and control performance was tested by different signal intensity and time of the day.

Results and discussions: Monitoring performance was favourable within 15 m distance with the tested ZigBee module, and a wireless communication network was established considering the communication distance and greenhouse length (i.e. 100 m). Remote monitoring and control was successful for all of the tested signal intensity and time of the day, although the data transmission speed was affected significantly.

Conclusion: Test results showed a promising result for remote monitoring and control of the system. For commercialization and practical application, the prototype needs to be tested under crop growing conditions to confirm the stability and durability.

Presentation

Basic tests of Chinese cabbage yield monitoring sensors for small-sized Korean harvesters

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http://doi.org/10.5281/zenodo.895446

Chinese cabbage is one of the major dryland crops, especially for Kimchi, in Korea. Recently Korean government promote mechanization of the dryland crop production operations to improve the current mechanization level of 56%. The demand of precision agriculture technology has been increased for improved performance and user comfort. Objective of this study was to conduct basic tests of potential alternative sensing approaches for Chinese cabbage yield monitoring for small-sized Korean harvesters. Two approaches were investigated: mass-based sensor using load cells and volume (or area)-based sensor using a CCD camera. The mass-based sensor was installed so that the cabbages discharged from the transportation part were contacted before they fell down to the collection part. Volume-based sensor was installed on the transportation part so that the top and side images of the Cabbages were captured. Area and volume of the cabbages were obtained from the images, and then calibrated to the mass. In overall, calibration tests provided coefficients of determination of 0.97 and 0.94 for the mass-based and volume-based approaches, respectively. Effects of the distance between the sensor and cabbage were not statistically significant. Data processing to minimize the vibration and slope effects should be improved. This study showed promising results for Chinese cabbage yield monitoring, but further study should be conducted to improve the performance for different varieties and under field conditions.

Presentation

Lessons learnt from field trials of a robotic sweet pepper harvester for protected cropping systems

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http://doi.org/10.5281/zenodo.895667

In this paper, we present the lessons learnt during the development of a new robotic harvester (Harvey) that can autonomously harvest sweet pepper (capsicum) in protected cropping environments. Robotic harvesting offers an attractive potential solution to reducing labour costs while enabling more regular and selective harvesting, optimising crop quality, scheduling and therefore profit. Our approach combines effective vision algorithms with a novel end-effector design to enable successful harvesting of sweet peppers. We demonstrate a simple and effective vision-based algorithm for crop detection, a grasp selection method, and a novel end-effector design for harvesting. To reduce complexity of motion planning and to minimise occlusions we focus on picking sweet peppers in a protected cropping environment where plants are grown on planar trellis structures. Initial field trials in protected cropping environments, with two cultivars, demonstrate the efficacy of this approach. The results show that the robot harvester can successfully detect, grasp, and detach crop from the plant within a real protected cropping system. The novel contributions of this work have resulted in significant and encouraging improvements in sweet pepper picking success rates compared with the state-of-the-art. Future work will look at detecting sweet pepper peduncles and improving the total harvesting cycle time for each sweet pepper. The methods presented in this paper provide steps towards the goal of fully autonomous and reliable crop picking systems that will revolutionise the horticulture industry by reducing labour costs, maximising the quality of produce, and ultimately improving the sustainability of farming enterprises.

Presentation

Big data system for disaster warning of solar greenhouse vegetables

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http://doi.org/10.5281/zenodo.895623

Background: Solar greenhouses are very popular in the north of China as a way of meeting the demand for fresh local winter vegetables. Nonetheless, they are more susceptible to biological and meteorological disasters, such as diseases, pests, fog, haze and cold temperatures. Although we have deployed many record keeping equipment and weather stations, we have lower efficiency of usage on data. Big data has great potential in the future. Thus, our aim is to investigate a big data system for disaster forecasting and control to efficiently capture long-term and up-to-the-minute environmental fluctuations inside greenhouses.

Methods: A greenhouse disaster survey database was designed from the most important place of solar greenhouse vegetable production, that is the area around Bohai Harbor, including Beijing, Tianjin, Shandong, Hebei and Liaoning Provinces. The comprehensive survey provided large amounts of data, such as greenhouse distribution and environment parameter monitoring, for the system. The authors developed and integrated some disease, pest and meteorological disaster warning models using disaster-chain theory. The system was developed using C# in .NET framework.

Results: A big data system for greenhouse vegetable disaster was developed combing with monitoring data for diseases and pests, meteorological data and production record data based on the internet of things, while visualization results were illustrated to provide a reference for the prevention decision. The system was applied in Beijing, Tianjin, Hebei, etc.

Discussions: The present system proposes a meteorological disaster framework which includes warning and management of related diseases and pests. Its innovation is in the use of disaster chain-styled theory for meteorological risk warning and management based on the idea of data-intensive scientific discovery.

Conclusion: A greenhouse vegetable disaster big data system was designed based on the internet of things and disaster warning models, providing a new meteorological service model to control greenhouse disaster, diseases and pests.

Poster

Development of an agricultural implement guidance system

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http://doi.org/10.5281/zenodo.1002310

Agricultural machinery automatic navigation technology is an important part of precision agriculture. In order to achieve accurate mechanical inter-rows weeding and agricultural vehicle navigation, an integrated navigation system of agricultural vehicle and implement based on GNSS and MV were designed. The system can reduce labor intensity, upgrade working accuracy, and improve the safety of operators. The system is a convenient, efficient and automatic agricultural implement guidance system, and easy to realize large-scale production.

Poster

Self-tuning pole assignment path tracking control for an autonomous self-propelled HighClearanceBoom sprayer in paddy field

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http://doi.org/10.5281/zenodo.1002883

Background: The Self-propelled HighClearanceBoom Sprayer is a kind of important paddy field management machinery, the realization of automatic navigation control is of great significance to improve the work efficiency and reduce the injury to the driver. Because of variable load in spray operation and sideslip in paddy field, navigation control is seriously disturbed, the path tracking accuracy is low and the stability is poor.

Methods: A path tracking controller was designed based on the pole assignment method. A self-tuning pole assignment algorithm was proposed based on the step response characteristics of two order navigation system. The self-tuning controller could automatically adjust the dynamic characteristics of the system according to the current lateral tracking error and keep good dynamic performance to suppress the interference of the sideslip objective and improve the navigation accuracy.

Results: The results showed that the self-tuning controller could effectively suppress the influence of the sideslip of the automatic navigation sprayer in paddy field, and improve the path tracking accuracy and stability. The maximum lateral tracking error was less than 0.1 m for straight trajectory tracking at the traveling speeds of 1.2 m/s.

Discussion: The self-tuning controller designed in this study is based on linear system, but the complexity of the paddy field environment will lead to the mismatch of the linear system model. In the future, the nonlinear adaptive control method based on online system identification should be used to design the navigation controller.

Conclusion: In order to suppress the interference caused by sideslip to the navigation control system of the Self-propelled HighClearanceBoom sprayer, a navigation controller with self-tuning pole assignment based on lateral tracking error was designed to improve the accuracy and stability of the path tracking in paddy field environment.

Poster

Development of crop detecting system using on UAV platform in precision agriculture

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http://doi.org/10.5281/zenodo.1002317

Farmland information perception is important in precision agriculture. To change the traditional ways of the agriculture measurement with destructive sampling and chemical test in the lab, the spectral sensor system were developed to measure the plant information based on the UAV platform. It involves rapid acquisition of spectral reflectance, data transformation and data management system. It could help and improve the production efficient in the precision agriculture. With the application of spectrum analysis and image processing technology, a crop detecting system using on UAV was developed.

Presentation

Machine vision for camera-based horticulture crop growth monitoring

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http://doi.org/10.5281/zenodo.893702

Plant growth and fruiting development monitoring is required for horticulture crop and irrigation management. However, this monitoring is typically manual, labour-intensive and conducted in a limited number of locations in the field which may not represent the whole field. Rapid crop assessment throughout the season can be achieved using machine vision analysis of images captured with cameras. High spatial resolution plant growth and fruiting information can be used for yield estimation and to manage site-specific irrigation and fertiliser application.

Camera-based plant sensing systems have been developed for high spatial resolution data collection from top views of crops. The sensing systems have been installed on overhead irrigation machines. The cameras on the irrigation machine were smartphones with an App installed to capture and upload images and GPS location at a time interval. These cameras automatically captured and uploaded images during irrigation events as the machine traversed the field. Image analysis algorithms have been developed to estimate canopy cover for peas and carrots, and flower counts for peas.

These cameras have been evaluated at sites in Kalbar in South East Queensland, Australia, and Palmerston North, North Island, New Zealand. This paper compares the image analysis results with ground truthing measurements that were collected at approximately weekly intervals at the sites, and electrical conductivity, reflectance, yield and soil type maps.

Presentation

Improved vision-based weed classification for robotic weeding – a method for increasing speed while retaining accuracy

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http://doi.org/10.5281/zenodo.891510

In this paper, we demonstrate how a deep convolutional neural network (DCNN) can be deployed in resource limited environments, such as robots, to reduce the inference time by more than an order of magnitude while retaining high classification accuracy and robustness to novel conditions. This is achieved by training a lightweight DCNN, or compressed model, via model distillation. We show that training models using this approach outperform training a similar model from scratch, using the same data, for weed classification. Using model distillation we are able to improve the accuracy from 97.1% to 97.9% for similar conditions (as the training data) and from 86.4% to 89.8% for different conditions (as the training data). This is in comparison to a traditional approach using robust local binary pattern features which achieves 87.7% for classifying in similar conditions and 83.9% for classifying in different conditions. Finally, we compare this compressed model to a complex fine-tuned model which achieves higher accuracy of 99.6% for the same condition and 95.8% for different conditions but has 100.0 times more parameters (larger model size) and is 40.6 times slower at computing the inference.

Presentation

Machine vision system grading of pine tree seedlings

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http://doi.org/10.5281/zenodo.895621

A PC-based machine vision system for grading pine tree seedlings has been tested at a forestry nursery. The machine has been designed to be implemented in the field at the point of harvesting, removing the need for extra handling steps. The machine measures the height, RCD and root quadrants and makes a decision whether to reject or accept the tree.

The grading specification for pine tree cuttings and seedlings appears to be black and white, with clear rules defining whether a tree is acceptable or not; however, the organic nature of the product introduces ambiguity into the decision. Three experts were gathered and asked to independently grade a raw lift of 200 trees with no knowledge of the other experts' decisions. A consensus was not reached on one in every four trees. The same set of trees was graded by placing them in the machine one by one. The machine achieved 97% agreement with the group of experts, ignoring the decisions on trees where they did not all agree.

The machine has been proven to be capable of making decisions on pine seedling quality comparable to that of an expert. It performed well in a shed under controlled conditions; however, the effect of an outdoor environment has yet to be determined.

Presentation

Investigation of the spatial variation of total soluble solids in postharvest mulberry fruit

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http://doi.org/10.5281/zenodo.891103

To better understand the ripening process of mulberry and find a suitable postharvest storage strategy, it is necessary to visualize the quality variation inside mulberry fruit. This study focuses on fast monitoring the Total soluble solids (TSS) variation inside postharvest mulberry fruit using hyperspectral imaging (HSI) technique. Mulberry fruits with different TSS contents were selected at different postharvest periods, and were stored in refrigeration and room temperature as control. During the storage, mulberry fruits were cut at longitudinal sections and hyperspectral images of treated and control fruit were obtained by a visible/near infrared (Vis/NIR) HSI system. When the spectral image acquisition was completed for each fruit, its reference TSS was determined immediately by a handheld refractometer. At last, a robust prediction model between the reflectance spectra of fruits and their TSS references were established using partial least square regression. Results showed that a good correlation was obtained between the reference TSS values and spectral information. The quantitative TSS distribution inside mulberry fruit was visualized. This study presents a rapid method of HSI for visualization of TSS distributions in fresh-cut mulberry fruit. To the best of our knowledge, this is the first study on using hyperspectral imaging to measure TSS distributions inside mulberry fruits. Hyperspectral imaging system supported by multivariate image analysis methods is a powerful tool in evaluating and visualizing the TSS distribution inside mulberry fruit at pixel level.

Presentation

Design of big data acquisition for professional grower based on smart agricultural machinery systems

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http://doi.org/10.5281/zenodo.889082

The last 20 years have seen an increase in agricultural technology and information systems intended to improve yields, reduce costs, and environmental sustainability production. However, these technologies haven't delivered to practical farmer yet. This research looks at the challenges of creating step changes for precision agriculture, how to make big data which obtains from agriculture machinery for young farmer. This presentation focused on the importance of big data solution for inheriting farm management. Smart rice transplanter, smart 2nd fertilizer applicator and yield monitoring combine harvester (i.e. smart agricultural machinery systems (SAMS)) have been employed in order to monitor spatial temporal variability of topsoil depth, soil fertility and crop status for variable rate fertilizer application. As a result of field experiment indicated that 7,000,000 dataset of soil information, 65,000 dataset of crop status and 10,000,000 dataset of yield dataset were observed from the SAMAS. Variable fertilization design based on the experience of professional farmers also result in 20% fertilizer cut than conventional way and 30% harvest efficiency was improved. We concluded that the determination of variable setting values in field management with big data, the algorithm can be reflected the judgment of professional farmers. We should not apply only from the scientific aspect.

Presentation

Development of smart 2nd fertilizer application system by using canopy sensor

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http://doi.org/10.5281/zenodo.889091

This research developed Smart 2nd Fertilizer Application System（SFAS）using canopy sensor to equalize growth of rice paddy and prevention from lodging upon harvest. The CropSpecTM was applied as a canopy sensor for measuring N status in order to operate variable application. The amount of fertilizer applied was determined by using measured value (S1) and producer's experience. The SFAS recorded geo-referenced information in order to apply for site-specific crop management exercises for creating a prescription map for other and future operations, as well as to provide an "as applied" application record for the grower. The result of field experiment, the correlation between N status and S1 was R2=0.57. The maximum value of S1 was 36.4, the minimum was 25.0 and the average was 30.7, respectively. This application system could reduce the amount of fertilizer among the rich N zone. As a result, the system could save 20% of fertilizer than conventional way. Result of crop yield sampling analysis, lodging spot produced 850kg/10a of rough rice, while brown rice was 600kg/10a. No-lodging spot produced rough and brown rice were 700kg/10a and 560kg/10a, respectively. No-lodging data indicated that the ratio of rough rice and brown rice weight (commercialization rate) was 9% higher than that of lodging spot data. In this presentation, we discussed how the variable rate application could contribute to prevent lodging and improve rice quality.

Presentation

Real-time lodging analysis for smart combine harvester

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http://doi.org/10.5281/zenodo.889089

In this project, we tried to develop technology to estimate yield by grasping lodging condition during harvesting operation using image processing. The purpose of this study was to investigate the relationship between degree of lodging and number of grain for estimating yield variability within a field.

100 Grain sample data was obtained from 18 fields (5.4ha). Lodging level was defined as 5 steps (i.e. level 1: 15, 2:30, 3:45, 4:60 and 5:75 degree, respectively). This study measured ground truth of whole kernels, brown rice weight and weight of waste, respectively. The result of observation indicated that weight of clean hulled rice at level 5 was 1.05 times larger than level 1. However waste rice at level 5 was 3.08 times as much as level 1. Level 1 tended to have higher percentage of ripened grains than that of level 5. The average N content and weight of winnowed rough of level 1 were 0.72% and 753.1kg/10a, level 5 of them were 0.79% and 832.7kg/10a, respectively. In addition, harvest time under level 5 condition was 2 times longer than level 1. The mention above, creating a lodging map during harvesting season would be important factor for strategy making of lodging prevention for future crop management.

Presentation

Evaluation of field condition by using smart rice transplanter

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Lodging of rice has become a big problem for large scale farmer during harvesting season. Investigating topsoil depth (TD) and apparent electrical conductivity (ECa) of paddy field will be the key to solve this problem. In this study, we developed smart rice transplanter, which could measure TD and ECa. The TD was measured by ultrasonic distance sensor (USS). The ECa was measured by soil electrical conductivity sensor (ECS). We defined that the ECa measured by ECS was soil fertility value (SFV). Each sensor could obtain data every one second. As a result of field test in 2016, total 740,000 of datasets were collected from 50ha paddy. The average of the TD was 19.8 cm while the maximum, minimum, and standard deviation (SD) of TD were 68.47, 7.45 and 6.62 cm respectively. The average of the SFV was 1.04 mS/cm while the maximum, minimum, and SD of SFV were 9.57, 0.07 and 0.68 mS/cm respectively. The result also revealed that high TD was observed in heading area due to machine turning inside the field. In this study, TD and SFV were also applied for variable rate fertilizer application. We designed variable rate ratio with 4 levels. Level 1 where high TD zone reduced by 30%. Level 2 where high SFV zone reduced by 20%. Level 3 where a little high SFV zone reduced by 10%. Level 4 where the other zone fertilized conventional amount. As a result, the smart rice transplanter saved 20% of fertilizer than conventional application.

Poster

Site-specific weed management in maize (Zea mays)

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http://doi.org/10.5281/zenodo.1002244

Site-specific weed management can increase crop production efficiency by minimizing herbicide input costs without compromising crop yields. A reduction in herbicide inputs resulting from site-specific weed management may also decrease the probability level of nonpoint pollution compared with conventional herbicide applications. A 4.5-ha field was selected to compare site- specific and conventional weed management techniques in a field location at Knoxville, TN. Variable rate applications (VRAs) of atrazine pre-emergence (PRE) followed by dicamba post-emergence (POST) were investigated for the reduction of herbicide inputs and their resulting impact on weed control and corn yield. VRAs of atrazine were on the basis of weed density data collected in Year 1. VRAs of dicamba were according to common cocklebur density evaluations within the field. Com- pared with conventional applications, atrazine usage was decreased by 43 and 32% in the site-specific application treatments in Year 2 and Year 3, respectively. VRAs of dicamba reduced herbicide inputs by greater than 45% for Year 2 and Year 3. Corn yields were similar for the conventional and site specific treatments in both years. On the basis of these data, site-specific herbicide applications have the greatest potential and least risk for managing weeds when POST or PRE + POST variable rate herbicide applications are used.

Poster

Estimating SPAD value, chlorophyll and mineral components using hyperspectral data of maize leaves

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http://doi.org/10.5281/zenodo.1002263

Background: Visible-infrared hyperspectral data have been widely used recently in remote sensing for nondestructive crop-quality estimation in the field. The authors applied hyperspectral remote sensing to the field of feed maize to investigate the estimation of feed contents of the whole maize plant (including leaves, stems, and grains) from the hyperspectral data of maize community.

Methods: In this study, as a preliminary step to the estimation of feed contents, we attempted to estimate the SPAD value, chlorophyll (a, b and a+b), and mineral components (T-N, T-P, and T-K) contained in leaves from the hyperspectral data (390-983 nm, 60 bands) of maize leaves.

Results and discussions: Regarding the estimation method, we compared the estimation accuracy of two kinds of partial least squares regression (PLSR) using either all bands (60 bands) or only selected ones as explanatory variables. When all bands were used as explanatory variables, estimation was possible with accuracy that is sufficient for practical use for all parameters except chlorophyll b, phosphorus (T-P) and potassium (T-K) (R2 = 0.82-0.90, El = 19.7-24.5, El Rank= B). When waveband selection was conducted, it was judged that all parameters except phosphorus (T-P) and potassium (T-K) can be estimated with accuracy that is sufficient for practical use (R2 = 0.78-0.91, El = 19.6-21.7, El Rank= B). Based on the relation between measured values and estimated ones in verification, it was judged that actual estimation was possible for three parameters: the SPAD value, chlorophyll a+b and nitrogen (T-N).

Conclusion: The results described above demonstrate that the SPAD value related to the greenness (depth of green color) of the leaf blade, chlorophyll a+b and nitrogen (T-N) can be estimated by applying PLSR, or PLSR with band selection, to hyperspectral data of maize leaves.

Poster

Dynamic image process method for vegetation indexes in precision agriculture

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Background: Currently, aerial images, tissue analyses, soil sampling analyses, and soil plant analysis development (SPAD) readings are used to assess the crop nutrition status. The remote sensing techniques are very popular and used in many areas including PA in these days. But in the case of remote sensing which uses passive light system, the image data should be processed for vegetation index in PA. This paper presents the dynamic calibration image processing method of a CMOS image sensor, which uses three channels (green, red, blue) of crop images to determine crop reflectance for vegetation index.

Methods: The real-time crop image was acquired using CMOS image sensor. The crop images were acquired during a different light condition from sunny to cloudy. And dynamic calibrations were investigated for a true reflectance calculation. The background elimination algorithm and the crop canopy reflectance analysis algorithm were also used for this research.

Results: To eliminate the effect of ambient illumination variation on gray levels of crop image caused by either the clouds or the solar radiation angle, the dynamic calibration model calibrates the measured crop reflectance. The core of this investigation is the calibration methods between the CMOS image and the reflectance in crops. Some noticeable relationships between the CMOS image reflectance and light condition were found from this study.

Discussions: Development of a system would identify where vegetation index is low and would apply fertilizer only to these identified areas.

Conclusion: The developed dynamic calibration model can be used to compensate for the variation of ambient light caused either by the weather condition or the solar zenith angle effectively. The CMOS image sensor is capable of detecting crop reflectance reliably in real-time.

Presentation

Enhancing Pigeon pea production in India through precision agriculture

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Background: Pigeon pea is an important commercial pulse crop for the farmers of Karnataka a south Indian state. Though the crop has been cultivated for many years in the region, the yield somehow is not up to desired levels due to uncertainties of rainfall extremities, conventional variety, seed rate, spacing and plant population and poses challenge towards sustainability in production.

To counteract this, the technical intervention by adopting principles of precision agriculture like use of right input in right time in right quantity in right manner like direct seeding of pigeon pea in main field to replace the conventional method of drill sown seeds so as to maintain adequate plant population for compensating yield loss is being explored as a suitable strategy to help enhance yield/productivity, improve quality with greater resource use efficiency and avoiding soil, air and food pollution.

Method: In this context, an experiment in farmers fields (25) under farmers' participatory was taken up during 2016 Kharif season with the objectives of studying the feasibility and its suitability in the area for further refining the technology of direct seeding of pigeon pea. Three varieties viz., GRG-811, BSMR-736 and ICPH-2740 with 500 grams of seeds (2900 seeds) bio- treated were sown under 6' X 3' spacing with protective irrigation during the crop growth.

Results: The study revealed that, there was 100 percent germination and crop stand with optimum number of branches with pods in all the three genotypes tested with yield levels varied with genotypes ranging from 700 to 1200 Kgs of grains and an additional seed yield to the tune of 30.00 percent was realized under dibbling and was largely attributed to 10 % higher pods/ plant.

Discussions: Due to adequate space, light and air, the crop performed well.

Conclusion: Thus the study confirmed the feasibility of adopting principles of precision agriculture in pigeon pea farming.

Key Words: Precision Agriculture, Pigeon pea, India, Dibbling, Karnataka, Right input.

Presentation

Sequential decisions in digital agriculture - a cybernet-ICS perspective

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http://doi.org/10.5281/zenodo.895663

As digital technology starts to disrupt the agricultural sector and it becomes feasible to generate appropriate data, there is a great opportunity for developing and deploying novel decision and system-theory tools to assist with the management of agricultural processes as well as whole food-production systems. Agricultural Cybernetics takes a system view of agricultural production for the analysis and design of management strategies to control, optimise, and make crop behaviours of agricultural production systems robust while exploiting the intrinsic feedback information-exchanging mechanisms that these systems exhibit. Feedback is a powerful tool, but it is also subject to fundamental limitations, which when poorly understood can lead to underwhelming results as well as wasting time and resources. Cybernetics provides proven tools and processes to answer fundamental system-related questions that are directly applicable to agriculture: Can we achieve desired crop system behaviours given particular means to act on the system? Is it possible to extract the required information from the data collected? Conversely, what is the adequate infrastructure for data generation given the information requirements related to management? Is the management strategy robust to different sources of uncertainty associated with data, mathematical models and knowledge used in the analytics? The key to answering these questions lies in understanding concepts related to the characterisation of uncertainty, information, decision problems, and how system-feedback structures process information. This paper points to key system concepts applicable to in-season management of crops whereby a sequence of decisions have to be made as part of the management strategy. This relates, for example, to activities such as irrigation, nutrition, and pest-and-disease management. It discusses the potential use of cybernetics tools for analysing and solving these management problems. The material presented has a bearing on the choice and design of infrastructure for data generation, the adoption of data analytics, the formulation of decision problems, and the potential effectiveness and robustness of management strategies, and their return on investment.

Presentation

Robotic weeding – from concept to trials

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This paper reports on the use of robotic selective mechanical cultivation as an alternative method to herbicide control for managing weed species in zero-till cropping systems. Existing best-practice technology in weed spot spraying utilises infrared technology to detect and selectively spray weeds using herbicide at quantities significantly less than those used in normal blanket spray applications. This reduction in the herbicide de- creases operational costs and can be beneficial for the environment; however, the capital investment in the technology is substantial for farmers who wish to own and operate their equipment. While effective in reducing overall herbicide usage, the technology has done little to tackle the rapid evolution of herbicide resistant weed species. As a potential solution to this issue, our research over the past three years has been focused on the development of non-chemical methods of weed management utilising robot-enabled selective mechanical weeding. Used in conjunction with a robotic vehicle platform, a mechanical weeding array is capable of working throughout the day and night. The weeding tools have been designed to be removable and inter-changeable, allowing the use of tools especially designed for different weed species, weed densities, and soil types. The system developed consists of a one-degree-of-freedom array of weeding tines, actuated into the ground in time to remove individual weeds. Sensing of the weeds is enabled by a vision-based plant detection and classification system, while the timing for the implement actuation to hit the weed is determined as a function of the robot speed. The field trials reported in this paper demonstrate the potential of this robotic system for individualised weed treatment and multi-mode weed management methods. In particular, a trial of the mechanical weeding array in a fallow field over six weeks maintained the weed coverage in robot treated sections to be 1.5%, compared to 37% in the control areas not treated by the robot—a reduction in excess of 90% in weed coverage.

Presentation

UAV-based vineyard water status forecasting, univariate and multivariate models or artificial neural networks?

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Background: Stem water potential (Ψ_{stem}) is commonly used to assess water stress (Choné et al., 2001; Williams and Araujo, 2002) and irrigation scheduling (Girona et al., 2006; Jones, 2004). However, the ground-based measurement of Ψ_{stem} provides data with low spatial and temporal resolutions which hinder the spatial variability elucidation (Acevedo-Opazo et al., 2008). Using the remotely sensed multispectral information, it is possible to correlate physiological parameters in a non-invasive way (Baluja et al., 2012; Bellvert et al., 2015; Bellvert et al., 2014; Berni et al., 2009; Li et al., 2016; Rey et al., 2013; Zaman-Allah et al., 2015). However, vegetation indices may not yield reliable Ψstem with stable performance (Rapaport et al., 2015; Stagakis et al., 2012; Van Beek et al., 2013). This study presents a comparison between different methodologies to predict water status variability using multispectral information obtained from an UAV.

Methods: This study was carried out in a Carménère vineyard located in Talca, Chile. Four treatments and repetitions of regulated deficit irrigation varying from non-stressed to severe stressed were induced. Ψ_{stem} measurements and multispectral information of 530, 550, 570, 670, 700 and 800 nm obtained onboard an UAV were collected in 2014 and 2015. Univariate and multivariate linear models and six artificial neural network (ANN) models were applied to the randomly selected 80% of the collected data and the models were validated against the rest 20% of the data per treatments. Finally R^2, slope, RMSE, ER were calculated to assess accuracy of the prediction.

Results: The prediction accuracy for both linear models were increased dramatically by ANN models. R2, slope, RMSE values for the best linear models were 0.35, 0.05, 0.32 and 0.87, 0.96, 0.12 for the best ANN model. Finally, the best ANN and linear models were applied to the whole aerial images and compared.

Discussions: The best linear model showed lower predictability compared with the best ANN because conventional multispectral indices just detect indirect changes produced by water status. The best ANN model included 550, 570, 670, 700 and 800 nm information, which was consistent with Rapaport et al. (2015).

Conclusion: ANN model (excluding information of 530 nm) was able to predict Ψ_{stem} accurately compared with other ANN and univariate and multivariate linear models.

Presentation

Multi-temporal landsat algorithms for the yield prediction of sugarcane crops in Australia

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http://doi.org/10.5281/zenodo.891091

Accurate with-in season yield prediction is important for the Australian sugarcane industry as it supports crop management and decision making processes, including those associated with harvest scheduling, storage, milling, and forward selling. In a recent study, a quadratic model was developed from multi-temporal Landsat imagery (30 m spatial resolution) acquired between 2001-2014 (15th November to 31st July) for the prediction of sugarcane yield grown in the Bundaberg region of Queensland, Australia. The resultant high accuracy of prediction achieved from the Bundaberg model for the 2015 and 2016 seasons inspired the development of similar models for the Tully and Mackay growing regions. As with the Bundaberg model, historical Landsat imagery was acquired over a 12 year (Tully) and 10 year (Mackay) period with the capture window again specified to be between 1st November to 30th June to coincide with the sugarcane growing season. All Landsat images were downloaded and processed using Python programing to automate image processing and data extraction. This allowed the model to be applied rapidly over large areas. For each region, the average green normalized difference vegetation index (GNDVI) for all sugarcane crops was extracted from each image and overlayed onto one time scale 1st November to 30th June. Using the quadratic model derived from each regional data set, the maximum GNDVI achieved for each season was calculated and regressed against the corresponding annual average regional sugarcane yield producing strong correlation for both Tully (R2 = 0.89 and RMSE = 5.5 t/ha) and Mackay (R2 = 0.63 and RMSE = 5.3 t/ha). Moreover, the establishment of an annual crop growth profile from each quadratic model has enabled a benchmark of historic crop development to be derived. Any deviation of future crops from this benchmark can be used as an indicator of widespread abiotic or biotic constraints. As well as regional forecasts, the yield algorithms can also be applied at the pixel level to allow individual yield maps to be derived and delivered near real time to all Australian growers and millers.

Poster

Can sensors and crop models predict the need for late-season nitrogen for protein enhancement in spring wheat?

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http://doi.org/10.5281/zenodo.1002269

Background: Grain protein content impacts the market value of hard red spring wheat in North America. A post-anthesis application of aqueous UAN can increase protein levels. Predicting grain protein content prior to flowering would help growers determine the need for this extra nitrogen application. Our objective was to determine how useful pre-flowering NDVI values and crop models might be in predicting grain protein.

Methods: Field experiments with several N rates were conducted in multiple environments from 2013 to 2016. NDVI was measured at several crop growth stages. Regressions with NDVI and protein were calculated. Since low grain protein commonly occurs when yields are high, the DSSAT crop growth model was used as a means of predicting yield based on weather inputs.

Results: NDVI was found to be predictive of grain protein in some seasons (r2>50) but not others. Normalized NDVI was more likely to be predictive than NDVI alone. Predicting low protein levels (less than 12%) was more likely than moderate to high levels. The OSSAT model was more effective in predicting yield when predicted weather data was used at later growth stages.

Discussions: NDVI values tend to saturate before protein reached 13%, reducing its value to predicting only very low protein levels. Since weather plays such an important role in yield development, the DSSAT model is best at predicting a range of yield outcomes rather than a specific outcome.

Conclusion: Normalized NDVI values can be used in predicting very low protein levels. This finding could be adapted to the field level by using a drone that collects NDVI in fields with an N rich strip. The DSSAT model can predict yield prior to flowering but the outcome is subject to variable post-anthesis weather that in many environments may be highly variable and difficult to predict, limiting its usefulness.

Poster

Detection of rice grain using low altitude UAV images at growing stage

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http://doi.org/10.5281/zenodo.1002353

Background: The advances in precision agriculture have improved the monitoring system of agricultural crops growth and yield estimation. Yield is the primary key for precision crop management. Estimation of rice yield within the field, could be an option to find out higher or lower yield zone. Problem identification would be easier and suitable practices can be applied to improve yield. So, the main objective of this paper is to propose an image processing technique to detect the rice grains using low altitude unmanned aerial vehicle (UAV) images.

Methods: We propose an image processing algorithm. Firstly, the algorithm read initial RGB image and a noise filter was used to remove the noise. Secondly, it converted RGB to L*a*b* color space and thirdly, the k-means clustering was used to classify colors in 'a*b*' space. Finally, reshape by cluster indexing and labelling of the pixels in the image was attained using k-means and then image segmentation by color was completed. On segmented image, by using k-mean clustering, blob of the rice grain panicles were gathered as one. The estimation of area of segmented grain panicles and leaves were done.

Results: Proposed method have shown that, the area of segmented rice grain panicles and leaves were accurately estimated. The segmentation method is rapid and easy to apply but in some cases, it is needed to adapt the light of images.

Discussions: Our method was efficient for area estimation of rice grain panicles using UAV images. In some cases we get less significant results due to the noise caused by reflectance of bared soil.

Conclusion: The proposed method is able to estimate rice grain panicles and using this method we expect to estimate the volume of rice grain to predict the grain yield and the harvesting time by observing the grain and leaves color and size.

Acknowledgement: This Research was supported by Korea Institute of Planning and Evaluation for Technology in Food, Agriculture, Forestry and Fisheries (IPET) through Agriculture, Food and Rural Affairs Research Center Support Program (Project No: 714002–07) funded by Ministry of Agriculture, Food and Rural Affairs (MAFRA).

Poster

Yield prediction of maize crop (Zea Mays) by integrating NDVI with yield monitor data

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http://doi.org/10.5281/zenodo.1002331

Monitoring of crop growth and forecasting its yield well before harvest is very important for better crop and food management. Unmanned aerial vehicle (UAV) installed with near infrared camera (NIR camera) is a potentially important for acquisition of data to provide spatial and temporal data for site specific crop management. Hence, the study has been carried out to develop the empirical relationship for Infrared camera and N-Tester data at different crop growth stages with yield data for maize crop. Infrared camera and N-Tester were used to collect data at different growth stages of the crop to develop relationship with the yield monitor data. The near infrared (NIR) camera was mounted on parrot AR. Drone 2.0 frame for image acquisition. Based on aerial images of the plots the Normalized Difference Vegetation Index (NDVI) was calculated. Maize field was harvested by the combine harvester mounted with yield monitor to generate the yield map of the field. Yield is the measure for quantifying the agricultural input and crop management. Yield map is vital for site specific crop management. Statistical linear regression models were used to develop empirical relationship between the NDVI and N-Tester data and yield at different growth stages of maize crop. The yield prediction equations have maximum) coefficient of determination (R20.84 for N-Tester and 0.86 for NDVI (NIR camera) at silking stage (R1).NDVI and N-tester values were positively correlated with yield data at all growth stages of maize.

Presentation

Integrating geographic information system and remote sensing in predicting rice grain protein

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http://doi.org/10.5281/zenodo.891527

Application of remote sensing and GIS has great potential in crop monitoring and retrospectively can set the strategies and management practices as to maximize yield and grain quality. In this study, UAV remote sensing data were utilized to predict grain protein content. Total images were differentiated into two groups as cloud free and cloud shadowed. On one hand for the cloud free samples, the vegetation index, NDVI derived from the canopy spectral reflectance was significantly correlated to the final grain protein content (R2=0.553, RMSE=0.210%, n=14). On the other hand, for cloud shadowed samples, the result demonstrated that vegetation index, NDVI was significantly correlated to the final grain protein content (R2=0.479, RMSE=0.225%, n=35). Different layers and files were created to manage, store and mapping grain protein using ArcGIS. All test fields at first and then, the NDVI image of each test field was also converted to shape file. Henceforth, the information of each field was displayed using overlap function. Therefore, protein content of rice in each field can be mapping by GIS and possibly forecasted using canopy or images spectral reflectance at grain filling stage.

Poster

Robotic harvesting of kiwifruit

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http://doi.org/10.5281/zenodo.1002294

Harvesting kiwifruit, New Zealand's largest horticultural export, is a labour intensive task. An automated harvesting system is presented that utilises a robotic arm controlled by a machine vision system.

Being electrically actuated, the arm provides highly accurate spacial positioning, necessary for carrying out the motions involved with picking. A gripper, mounted to the end of the arm, mimics the action of a human harvesters hand when detaching fruit.

We find that a combination of a snap rotation of the fruit whilst pulling the fruit away from its stem is an effective means of fruit detachment. This action minimises both the amount of force applied to the fruit and the time to detach.

Presentation

Implications of plant-to-plant variability on spatial variability of yield in vegetable crops

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http://doi.org/10.5281/zenodo.891089

Plant population and environment vary spatially within crops and determine yield potential. Optimising management to account for the effect these factors have on yield potential could improve production outcomes. Under optimal conditions spatial variability in established population and interplant variability drives within-field yield variability. Here we obtain a measure of intra-plant and population variability in a field of onions, and develop a novel approach to define management zones within the field based on population and environment effects on yield potential.

Plant spacing and individual bulb weight of c. 2000 onion plants were measured across four different areas of a field with optimal growth. Density distributions were fitted to bulb weight and plant spacing. In addition, 104 point samples (1.8m2) were collected as a grid to determine spatial variability of yield and population. From the distribution functions, the range of yield and population under optimal growth was determined.

Potential yield was 92 tha-1 at 59.8 plants m-2. Bulb mass was distributed normally (154g ± 49g) and based on this variability, optimal yield ranges are above 83 tha-1. Yields below 60 tha-1 were defined as severely growth limited at the standard population. Expected population range was 54–-78 plants m-2. We combined these layers to develop a management zone map. This approach identifies areas in the field where tactical in-season management can improve yield of growth limited areas, or where longer term strategic management is needed to optimise future plant establishment and population to improve overall outcomes.

Poster

Design and construction of a remote monitoring and control system for a dehumidifier combined with a heating module

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http://doi.org/10.5281/zenodo.1002866

Background: Protected cultivation (e.g., greenhouse) is spreading mainly for high-income crops such as paprika, strawberry, and tomato. The temperature and the humidity are especially important during cultivation. A dehumidifier combined with a heating module is under development. In the study, a remote monitoring and control system for the prototype was designed and constructed.

Methods: The dehumidifier prototype was composed of a dehumidifier, a fan blower, and heating modules. The remote monitoring and control system was composed of temperature-humidity measuring sensor network, a central processing module, a dehumidifier network, and smartphone application. First, the sensing network was tested for different communication distances and number of data variables. Second, remote monitoring and control performance was tested using the smartphone application by signal intensity and time of the day.

Results and discussion: Monitoring performance was favourable within 15 m distance with the tested ZigBee module, and a wireless communication network was established considering the communication distance and greenhouse length (i.e., 100 m). Remote monitoring and control was successful for all of the tested signal intensity and time of the day, although the data transmission speed was affected significantly. Components of the dehumidifier were successfully controlled within 30 s.

Conclusion: The remote monitoring and control system was tested only under experimental conditions. For improved performance and practical application, the prototype needs to be further tested under crop growing conditions, and the control algorithm needs to be also improved.

Presentation

The impact of spatial variability in soil nitrogen and the value in its management: a case study

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http://doi.org/10.5281/zenodo.895491

Variable rate nitrogen (VRN) management strategies seek to optimise the nitrogen (N) supply to match crop demand, both to maximise farmer profitability and minimise environmental risks. Despite potential benefits, there has been comparatively little work looking at the value proposition underpinning VRN. Gridded soil samples from a cropping paddock in Hawke's Bay, New Zealand, were characterised for residual mineral N and a bioassay used to quantify N mineralisation potential. These data were used in APSIM, a systems model, to estimate production outcomes under three different N management strategies in an irrigated and non-irrigated maize cropping system. Predictions showed that yield was comparable between management scenarios, while VRN resulted in lower residual soil N at harvest for both irrigated and non-irrigated systems. While these results are for a single paddock, they demonstrate that in this circumstance the implementation of VRN significantly improved environmental outcomes without impacting gross margins.

Poster

Indoor aquaponic system design and analysis of its nitrogen cycle using Ion Selective Electrode (ISE)

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http://doi.org/10.5281/zenodo.1002340

Background: The AquaPonic system is an eco-friendly recycling method that can save energy and reduce the impact of environmental pollution from fish manure by utilizing it as a nutrient for plant growth. The aquaponic system is required to measure and control the suitability and efficiency of the circulation system depending on the concentration of the ammonium ion and the nitrate ion. For the measurement of nitrate and ammonium ions, ISE (Ion Selective Electrodes) were fabricated and applied to the designed system.

Methods: ISE were prepared for the measurement and analysis of ammonium and nitrate ions, which are the most important components of nitrogen circulation in the fish excrement of the designed aquaponic-system. The temperature, humidity, light composition and light intensity of plant growing area were controlled to collect meaningful information about growth of the plant. Lettuce was cultivated in a total of 60 ports and cultivated in a hydroponic cultivation method using fish excrement as a nutrient. Nitrate and ammonium ions were measured at 24 hour intervals for 1 month of growth of tilapia and lettuce. In order to investigate the growth of lettuce, weights and length were collected and the images of tilapia were obtained at feeding to determine the growth of tilapia.

Results: The analysis of the weight, length, and nutrients of the lettuce grown in the designed aqua phonics system showed that the designed aquaponic-system is an efficient system.

Discussions: In order to design an aquaponic-system for various crops and species, it is considered necessary to conduct experiments on aquaponic-system which combines various crops and species. Further research on the algorithm that can control the system in optimum environment is needed by collecting information about growth of plant and fish in controlled environment.

Conclusion: It is expected that further research on the development of algorithms that can determine the optimum growth environment by acquiring the growth information as changing the growth environment through the controllable system.

Presentation

Application of statistical machine learning algorithms in precision agriculture

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http://doi.org/10.5281/zenodo.895303

Remote sensing can facilitate rapid collection of data in agriculture at relatively low cost. Advancements in unmanned aerial vehicles and sensor technology, along with a significant reduction in the cost of acquiring data, have enabled us to collect and process remote sensing data in real time. Approaches based on remote sensing data are widely used in precision agriculture for estimating crop and soil characteristics such as leaf area index, biomass, crop stress, evapotranspiration, crop yield, and soil organic matter. These approaches typically use predictive models (e.g., linear, quadratic, power or exponential) that are based on ordinary least square (OLS) regression. However, the performance of these predictive models deteriorates when the effects of sun-surface sensor geometry, background reflectance and atmosphere-induced variations on spectral reflectance or spectral vegetation indices are larger than the variations in the crop or soil characteristics of interest. Any errors in the predicted soil and crop characteristics may, in turn, adversely affect farm inputs, farm outputs and thus the net profits. In recent years, machine learning algorithms such as artificial neural networks, support vector machines and Gaussian processes are being explored for developing predictive models for agricultural applications, especially since these algorithms are known to provide more accurate predictions than OLS. In this paper, we describe and experimentally compare the accuracy of OLS and statistical machine learning models for estimating crop water use (or evapotranspiration). We show that models based on machine learning algorithms provide significant improvement in accuracy in comparison with a state of the art energy balance model based on OLS. We use this example to highlight the potential benefits of the use of statistical machine learning algorithms in precision agriculture.

Presentation

Tech transfer or co-innovation: communicating weather forecast for irrigation management

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http://doi.org/10.5281/zenodo.895392

Irrigation in many regions of New Zealand can be managed using a better understanding of rainfall. However, access to reliable rainfall forecasts and the lack of understanding of current irrigation demands preclude many farmers from making informed irrigation decisions. A pilot study that combined current irrigation demands and short-term (2-6 day) rainfall forecast to enable informed irrigation decisions was conducted in a South Island river-based irrigation scheme. Pilot study farmers were provided near-real time access to on-farm measured soil moisture and region-specific weather forecasts. Water use efficiency was described as absence of irrigation-induced drainage below root zone. Initial results indicated that farmers used weather forecast for irrigation scheduling during shoulder season (Sep-Oct. Mar-Apr) but less so during peak season (Nov-Feb). Because of the potential unreliability of river supplies, farmers tend to practice a “just-in-case” approach where irrigations are scheduled around availability of river supply rather than crop demand and forecast rainfall. To enable the better uptake of weather forecasts for irrigation management, a combination of increasing the reliability of the water supply and accessibility of reliable weather forecasts, are necessary. While a tech transfer approach may enable hydrological and technological changes to irrigation management, our study also highlighted that to achieve a behaviour change, it is important to include collaboration, co-innovation and co-learning of irrigation management.

Presentation

User-technological index of precision agriculture

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http://doi.org/10.5281/zenodo.895653

To determine the relationships between technological innovation, economic effectiveness and practical usability is one of the main goals of precision agriculture. There is real demand of farmers for technological development for their tools, but many technologically advanced methods have failed to reach their expectations in practice. The effectiveness and usefulness depends on local conditions, cultivated crops and varies in different countries.

For the comparison between the methods of precision agriculture in terms of the relationship of technological advancement and application in practice was designed "user - technological index of precision agriculture" (UTIPA).

UTIPA is based on the mutual sharing of ideas and experiences between industry-focused community of people related to precision agriculture - farmers, technology suppliers and researchers. It includes areas of crop production, livestock production and forestry. Evaluation of different methods is conducted from the perspective of technological sophistication and usability in practice. Obtained data is processed by various statistical methods including cluster analysis and then visualized and made available online for the whole community.

Keywords: Precision agriculture, user accessibility, technological sophistication, technology, agriculture

Presentation

Hardware and embedded algorithms for real time variable rate fertiliser applications

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http://doi.org/10.5281/zenodo.895528

Efficient use of fertilisers, in particular the use of Nitrogen (N), is one of the rate-limiting factors in meeting global food production requirements. While N is a key driver in increasing crop yields, overuse can also lead to negative environmental and health impacts. It has been suggested that Variable Rate Fertiliser (VRF) techniques may help to reduce excessive N applications. VRF seeks to spatially vary fertiliser input based on estimated crop requirements, however a major challenge in the operational deployment of VRF systems is the automated processing of large amounts of sensor data in real-time. Machine learning (ML) techniques have shown promise in their ability to process these large, high-velocity data streams, and to produce accurate predictions. This paper will use a simulation testing methodology on real hardware to compare two existing ML algorithms and a prototype implementation of a newly developed algorithm for their applicability to VRF application.

Presentation

Variable rate irrigation management for soybean and corn

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http://doi.org/10.5281/zenodo.893636

Variable rate irrigation (VRI) is a new irrigation method developed in precision agriculture. VRI technologies allow the producers to site-specifically apply irrigation water at variable rates within a field to adjust the temporal and spatial variability in soil and plant characteristics. Use of VRI in agricultural production has the potential to improve water use efficiency. Developing VRI practice and documenting the benefits of VRI to producers are critical to accelerate the adoption of VRI technologies. Comparison of VRI with uniform rate irrigation (URI) in soybean and corn crops was studied in Stoneville, Mississippi, USA. A center pivot VRI system was employed for delivering irrigation water. Soil apparent electrical conductivity (EC) of the fields was used to delineate VRI management zones and create VRI prescription. Irrigation was scheduled using soil moisture content measured by soil moisture sensors. Crop yield and irrigation water productivity in VRI treatment was compared to that in the URI treatment. There was no significant difference in yields of soybean and corn between VRI and URI treatments. Compared to URI, VRI treatment saved 25% irrigation water in soybean and 21% irrigation water in corn. Irrigation water productivity (WP) of VRI was 31.2% and 27.1% higher than the URI in soybean and corn, respectively. Results demonstrated that VRI management was superior to the URI in terms of water use efficiency. Soil EC coupled with soil physical properties could be used to establish VRI management zones. Development of novel algorithms with more inputs to site-specifically determine appropriate amount of water to apply is a major challenge facing VRI industry.

Poster

Growth monitoring of horticulture crops using unmanned aerial vehicle (Part 1) - field monitoring of potatoes

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Background: Precision agricultural techniques using information such as precise crop growth conditions in fields have attracted attention recently. One technique uses remote sensing methods for field monitoring. Remote sensing for agriculture using satellites and aircraft has been used widely. Actually pilotless remote sensing is anticipated for use with test fields. Therefore, we investigated field monitoring techniques using unmanned aerial vehicles (UAVs) to obtain horticulture crop information.

Methods: In 2016, aerial images were taken on July 12, 24, and 31. For sensing tests, potato plants were set on 11 test blocks on July 31. Image analysis was done using a composite photograph of an Ortho image comprising about 150 aerial photographic images.

Results and conclusion: Composite aerial photographs of the Ortho image showed potato leaf etiolation and differences of vegetation. The G/R ratio of aerial images decreased as the plant stage advanced. This monitoring system can elucidate potato field plant conditions from aerial photographic images that include information about test blocks.

Poster

Study on agricultural implement height measurement method based on 2D-SLRF

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Background: Agricultural implement and working object to maintain the stability of the operating height can improve the quality and efficiency. To provide accurate operating height between implement and working objects, this paper proposes a kind of agricultural implement operating height measurement method based on 20 Scanning Laser Range Finder (20-SLRF).

Methods: The row information that obtained by 20-SLRF scanning vertical is corrected using an Attitude and Heading Reference System (AHRS). Then, the data is analysed based on mode principle, and different distance level sets are collected. The weighted fusion algorithm is used to calculate the agricultural implement operating height.

Results: The test results show that the 20-SLRF is mounted at 1510mm height position, the identification object (ground) accounting for more than 30.35%, the RMS error is 12.15mm, the maximum error is 19mm; the 20-SLRF is mounted at 1880mm height position, the identification object (ground) accounting for more than 29.61%, the RMS error is 4.32mm, the maximum error is 15mm.

Discussions: The method can accurately extract the relative height of the water surface of paddy field and the agricultural implement, the measuring error less than ±20mm.

Conclusion: The paper provides a new method for the precise levelling of paddy field.

Presentation

Smart & connected agrifood: beyond precision agriculture

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http://doi.org/10.5281/zenodo.895483

The digital revolution refers to changes sweeping the consumer goods and services sector made possible by advances in cheap, fast and reliable data acquisition and processing, sophisticated analytics, cloud computing services, wireless technologies, the Internet of Things and Artificial Intelligence. These offer the opportunity for a wide range of businesses to improve their operational effectiveness, and they have enabled the creation of a number of disruptive business models, e.g. Uber and Airbnb.

We asked: How might New Zealand's horticultural value chains be transformed or disrupted by the digital revolution? We then considered the technology platforms that would be necessary to enable this transformation. The technology platforms we identified are: sensor networks and connectivity; agri-food value chain informatics (including consumer insights); cloud computing service models; and cyberphysical systems (robotics). In addition, we need to consider social licence to operate.

The interdisciplinary development and integration of these platforms is an evolution of the precision farming concept (driving efficiency in largely agricultural commodity production systems), with added applicability to the whole value chain. We call this 'Smart & Connected AgriFood'.

Keywords: Smart & Connected, Horticulture, Industry 4.0, Food

Presentation

Identification of management zones based on soil and yield in slope citrus field

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http://doi.org/10.5281/zenodo.891508

This paper aims to 1) describe the spatial variation of soil parameters and yield in a steep slope citrus field and 2) identify the management zones based on the variation of soil properties and yield from the point of view of a row-based irrigation system. The test field was located on Iwagi Island, Ehime Prefecture. Soil volumetric water content (VMC) and electrical conductivity (EC) were collected from 51 locations at 3 different depths: the ground surface, 20 cm depth, and 40 cm depth. The yield data of 89 trees between 2010 and 2013 were also collected. Yield, VMC, EC, elevation and combination of yield and soil parameters were classified by cluster analysis with the fuzzy c-means method. The cluster analysis divided, VMC into 3 groups, EC into 3 or 4 groups, yield into 5 groups, elevation into 3 groups and combination of yield and soil parameters into 2 groups. The classified groups clearly showed the influence of cultivation of each variable. Comparing the row irrigation system with the cluster analysis results, row irrigation affected the yield and soil parameters. Some clustered groups in the same irrigation row were also observed. It is suggested that the existing row irrigation system can adjust the variability of the field yield.

Presentation

Digital twins in farm management: illustrations from the FIWARE accelerators SmartAgriFood and Fractals

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The Internet of Things (IoT) provides a vision of a world in which the Internet extends into the real world embracing everyday objects. In the IoT, physical objects are accompanied by Digital Twins: virtual, digital equivalents to physical objects. The interaction between real/physical and digital/virtual objects (digital twins) is an essential concept behind this vision. Digital twins can act as a central means to manage farms and has the potential to revolutionize agriculture. It removes fundamental constraints concerning place, time, and human observation. Farming operations would no longer require physical proximity, which allows for remote monitoring, control and coordination of farm operations. Moreover, Digital Twins can be enriched with information that cannot be observed (or not accurately) by the human senses, e.g. sensor and satellite data. A final interesting angle is that Digital Twins do not only represent actual states, but can also reproduce historical states and simulate future states. As a consequence, applications based on Digital Twins, if properly synchronized, enable farmers and other stakeholders to act immediately in case of (expected) deviations. This paper introduces the concept of Digital Twins and illustrate its application in agriculture by six cases of the SmartAgriFood and Fractals accelerator projects (2014-2016).

Presentation

Comparison of crop stress and soil maps to enhance variable rate irrigation prescriptions

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http://doi.org/10.5281/zenodo.893704

Soil textural variability within many irrigated fields diminishes the effectiveness of conventional irrigation management, and scheduling methods that assume uniform soil conditions may produce less than satisfactory results. Furthermore, benefits of variable-rate application of agrochemicals, seeds, and nutrients can be partially masked by applying inappropriate amounts of water. Center pivot irrigation systems can be equipped with variable rate irrigation (VRI) capability and commercial VRI systems have been shown to perform dependably. Soil properties will impact the optimal application rate for a given location, but that information will need to be supplemented with measures of crop stress for in-season adjustment. A field study was conducted at the University of Missouri Fisher Delta Research Center Marsh Farm at Portageville in 2016 with the objective to compare soil and in-season stress maps to help determine their relationship. Apparent soil electrical conductivity (ECa) data were used to estimate the clay content and infrared thermometers (IRT) were suspended from the center pivot system to measure canopy temperature. While much of the growing season had adequate rainfall that prevented high water deficit stress levels, measurements on 5 July demonstrated spatial variability in canopy temperature and an integrated crop water stress index (iCWSI) that appeared to be correlated with soil texture. While seed cotton yield incorporated more than just the factors discussed in this report, areas of lowest clay content corresponded with the lowest yields. Additional data will be collected under a range of conditions and used for statistical comparisons of the observed effects.

Poster

Navigation control based on double antenna GNSS and pure pursuit model for agricultural vehicle

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http://doi.org/10.5281/zenodo.1002388

Background: The automatic navigation of agriculture vehicles is a key technology in precision agriculture and widely used in agriculture production. The method of agricultural machinery's position measurement, attitude measurement and path tracking control are key technologies in the automatic navigation system. behavior.

Methods: As the test platform by the LOVOL M904-D tractor, using double antenna GNSS receiver measures the position and attitude of tractor. According to the principle of carrier phase difference to obtain the high-precision position information and master-slave antennas baseline vector and according to the relationship between the heading angle, the roll angle and the master-slave antennas baseline vector to obtain the heading angle and the roll angle of agricultural machinery. Path tracking control of agricultural machinery adopts a new pure pursuit method that selects a tracking point in path planning and the direction of the navigation control points to the tracking point as the target heading. The angle between the target heading and the current heading of the body is treated as a decision wheel angle after limiting range.

Results: The experimental that navigation control mothed based on double antenna GNSS and new pure pursuit Model for agricultural vehicle show that the max tracking error is within 2.5 cm , the mean error is no more than 0.8 cm and standard deviation is less than 0.9cm in the condition that speed 1-1.2m/s and preview distance 1.5m.

Discussion: Does it affect navigation control accuracy that double antenna attitude measurement without pitch angle?

The white noise of the roll angle is larger, whether it needs to be filtered or fused with inertial navigation information?

How to change the preview distance to maintain stable and high-precision agricultural machinery navigation control when improving the speed?

Conclusion: The proposed method can satisfy the operation requirement of agricultural machine in the 1.2m/s speed.

Presentation

Automatic detection and identification of invasive arthropod pests for pest management and biosecurity

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http://doi.org/10.5281/zenodo.890220

Thousands of insect traps are deployed both in border surveillance and integrated pest management programmes, all of which need to checked manually to obtain any data on insect populations. As an alternative to this form of surveillance program we offer an automated system comprised of optical sensors and precise machine learning algorithms provide accurate identification and counts of trapped insects. This is achieved through the use of pseudo acoustic data derived from the wingbeat of the insect as it enters the trap. We are working to build a library of wing beat frequency data of relevant insects for the Asia pacific region to be used with the FarmSense algorithm, and will be testing this technology on farms and within border monitoring operations in the near future.

Presentation

Guidelines for governance of data sharing in agri-food networks

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http://doi.org/10.5281/zenodo.893700

Big Data is becoming a new asset in the agri-food sector including enterprise data from operational systems, sensor data, farm equipment data, etc. Recently, Big Data applications are being implemented to improve farm and chain performance in agri-food networks. Still, many companies are refraining from sharing data because of fear of governance issues such as data insecurity, or lack of privacy or liability, among others. To overcome such barriers for developments with Big Data, this paper aims at: 1) analysing governance issues in agri-food networks, and 2) introducing a set of guidelines for data-sharing. Based on a literature review, a framework for analysing agri-food networks was developed, with internal governance factors (efficiency, effectiveness, inclusiveness, legitimacy & accountability, credibility and transparency) and external governance factors (political, economic, social, technological, legal and environmental factors). The framework contributes to development of a set of draft guidelines. Accordingly, for each factor, the guidelines address issues, best practices and lessons learned from other projects and initiatives. The approach developed in this paper creates a baseline for possible future developments of Big data in terms of 1) upscaling of the guidelines at a global level, 2) refining and fine-tuning of the guidelines for context specific agri-food networks, and 3) contributing to solving governance challenges in data sharing. In the future, the relevance of Big Data in the agri-food domain is expected to increase, and so are the contributions of this approach.

Poster

Design and experiment on precision fertilization control system of rice transplanter side deep fertilization device based on the operation speed

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Background: Fertilization is an important process of rice production, which directly affects the yield of crops. The mechanization level of rice fertilization is very low at present in China, and the artificial fertilization requires a large amount of fertilizer which caused the uneven distribution. The rice side deep fertilizing is an ideal way of fertilization, the way apply the granular fertilizer to the side of rice seedlings with a certain depth, the way can reduce nitrogen fertilizer amount of 20%-30% compared with the traditional fertilizing operation. The side deep fertilizing technique has been applied by the side deep fertilization device installed in the rice transplanter. The working way of the most existing equipment is the mechanical transmission mode and complex in installation, it can't achieve precision control of the fertilization amount.

Methods: The study design the precision fertilization control system in order to achieve the requirements of the side deep precision fertilization operation. Its working principle is motor driven fertilizer and fertilization amount was adjusted according to the change of the rice transplanter's speed obtained by GPS. The fertilizing control software was designed use eMbeddedVisuaiC++ integrated development environment

Results: The study has tested the fertilization working performance of the control system in static condition. The coefficient of variation of each row fertilizer quantity is 2.3%, 2.1%, 2.2%, 1.8% in the speed of 10 r/min, 20 r/min, 30 r/min, 40 r/min.

Discussions: The result shows fertilizer amount consistency is good and relatively constant, fertilizer variation coefficient of each row is small at the same speed, average fertilizer amount increases linearly with the increasing of the rotation speed.

Conclusion: The control system was developed for side deep precision fertilization operation and it can meet the requirements of precision fertilization of the side deep fertilization device.

Presentation

Design and experiment of an embedded multi-function wireless sensor for multi-service agricultural information acquisition

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http://doi.org/10.5281/zenodo.891518

Multi-service agricultural information has several data forms including text, audio, image and video. How to rapidly acquire and wirelessly transmit multi-service agricultural information is an essential prerequisite for sustainable development of precision agriculture. Devices for agricultural information acquisition in precision agriculture have different varieties and various input/output interfaces; however, these devices have only one single function and are lack of extensibility. To meet the demand of multi-service agricultural information acquisition in precision agriculture, a multi-service agricultural information acquisition sensor node (MAIAS) with multi-function integration was developed based on Android. A SC7731 chip is used as microcontroller chip of the node. Combined with ADC interface, microphone, image sensor, WiFi and 3G mobile communication module, the node was designed for rapid acquisition and wireless transmission of multi-service agricultural information in form of text, audio, image and video. To verify the performance of agricultural information acquisition and wireless data transmission of the node, experiments were conducted to acquire data of soil moisture content, audio, image and video in laboratory conditions. Audio data were transmitted by 3G mobile communication networks; the average transmission rate was about 21KB/s. Considering of large data volume, image and video data was transmitted using WiFi network, with the average rate of 2.63MB/s. The results show that the node could be connected with sensors for text information acquisition by ADC interface, and could satisfy the requirement on data acquisition of audio, image and video. The results also indicate that the node was feasible for rapid acquisition and wireless transmission of multi-service agricultural information in precision agriculture.

Key words: Agricultural information acquisition, Wireless sensor, Analog and digital converter, Audio signal, Image sensor

Poster

Research on the self-feedback algorithm of grain yield monitor model based on combine harvester

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Background: In order to obtain real time grain yield information, a kind of grain yield monitor system based on photoelectric principle was developed.

Methods: It was consisted of sensor module, data collection module, GPS module and grain yield calculation terminal. After analyzing the working status of combine harvester and the simulation of scraper heap shape, a subsection type grain yield monitor model was proposed. For the accuracy of grain yield monitor system was affected by the elevator speed seriously, the model had considered the elevator speed as an input parameter.

Results: When the combine harvester worked at the normal status, grain volume had linear relationship with scraper grain thickness. In order to further optimize the quality of yield data, a new preprocessing method was also proposed based on elevator speed dynamic threshold value filter. Once the data was below 10% of the real time calculated scraper thickness, it was removed. Once it was above 10 times of the real time calculated scraper thickness, it was replaced by the normal value one second before. **Discussions:** In order to evaluate this new preprocessing method, original data, average filter data and dual threshold filter data were used to validate the model. The test results show that the proposed data preprocessing method could eliminate the singularity and improve the smooth of yield data, obviously.

Conclusion: The field experiment showed that validation error of the grain yield monitor model was less than 3%, which could satisfy the practical need.

Poster

Study on the correlation of volatile between brown rice plant hoppers and rice stem based on electronic nose

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Background: Brown rice plant hopper (BRPH) is one of the main insect pests for rice plant. To strengthen the acquisition of BRPH insect pest information has important significance for prevent and cure insect pests of rice plant. As one of the new tools of real-time acquisition of BRPH insect pest information, electronic nose has been preliminary studied in the detection of BRPH. But all of those studies are in the test phase and many questions still unexplored.

Methods: This paper used electronic nose (PEN3) sample the volatile of U31N (under the 3th-instar nymphs) and 031N (over the 3th-instar nymphs) and rice stem. Decrease the disturbance of electronic nose response values which caused by environment factors via remove benchmark value. Using principal component analysis (PCA), comparison of sensor response values, Euclidean distance (ED), fuzzy C- means clustering analysis (FCM) and loading analysis (Loadings) for analysis.

Results: The results of ED analysis prove the correctness of PCA and the comparison analysis of sensor response values. The classification accuracy of FCM for U31N, 031N and rice stem is 70%. The misclassifications are existed between rice stem and 031N, but not existed between rice stem and U31N.

Discussions: The classification effect of PCA is poor. Compare with 031N has two-part change trends of sensor value closed to rice stem, U31N only have one. We can preliminary infer that the correlations between 031N and rice stem are stronger than the correlation between U31N and rice stem.

Conclusion: According to Loadings results, we can speculate that in the young stage of BRPH's growth, BRPHs are less influenced by rice stem. But the influence will be enlarged with the increase of the age. This experiment indicates the correlations are exists between the volatiles of BRPH and rice stem, which supports scientific reference for further BRPH detection via electronic nose.

Presentation

Creating prescription maps from satellite imagery for site-specific management of cotton root rot

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Cotton root rot is a century-old cotton disease that can now be controlled with Topguard Terra Fungicide. However, as this disease tends to occur in the same general areas within fields year after year, site-specific treatment can be more effective and economical. The objective of this study was to evaluate GeoEye-1 and Sentinel-2 satellite multispectral imagery for creating prescription maps for site-specific management of this disease. A GeoEye-1 2-m image acquired in 2009 and a Sentinel-2A 10-m image acquired in 2016 were used to map cotton root rot in two cotton fields, respectively. The multispectral images were classified into root rot-infested and non-infested areas using unsupervised classification. To accommodate the potential expansion and temporal variation of the disease, a 10-m buffer around the infested areas was added as part of the treatment areas in the prescription maps. The prescription map from the GeoEye-1 image for Field 1 was used for site-specific fungicide application in 2016 and the disease was effectively controlled. Airborne 1-m multispectral imagery acquired in 2016 was used to validate the classification accuracy of the Sentinel-2A image for mapping the disease in Field 2. Although the Sentinel-2A image missed some small infested areas as compared with the airborne imagery, prescription maps with the 10-m buffer from the Sentinel-2A and airborne images were very similar. The results from this study indicate that historical satellite images with 10-m spatial resolution or finer can be used to create prescription maps for site-specific management of cotton root rot.

Presentation

Detection of the pumpkin flower to estimate its fruit position using a colour camera

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http://doi.org/10.5281/zenodo.891525

The number of farmers has decreased dramatically, and the average age of the famers is growing over 65 in Japan. Pumpkin is wildly planted in Hokkaido, because there is almost no requirement of spraying and weeding management after transplanting. Therefore, many farmers want to expand the production of pumpkins. However, it is a heavy job to harvest the pumpkins. An autonomous harvesting machine for the pumpkin is required to be developed. The objective of this study is to find out the fruit position of the pumpkin, which is the basic technology for the auto-harvesting machine. Because the colour of the pumpkin fruits is similar to their leaves, the position of the fruits is difficult to be detected directly. In fact, the position of the pumpkin fruits is similar with the position of the flowers. Because the colour of the flowers and leaves are near yellow and green, respectively, the flowers could be detected by an image processing method. In this study, a colour camera was utilized to capture the images at an outdoor field. The colour space of the image was transformed from red, green and blue (RGB) to hue, saturation and value (HSV). The yellow flowers were detected in the HSV colour space. An experiment was conducted at an outdoor field of pumpkin in Hokkaido, Japan at daytime and evening. The results show that the method can detect out the flower correctly at both conditions, though some errors occur at the conditions when the colour of the background was similar with the flowers, or the colour of the flowers became white when the flowers were withered.

Keywords: pumpkin, auto-harvesting, flower detection, RGB image, HSV colour space.

Poster

Monitoring and early warning system of vegetable pest based on Internet of Things

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http://doi.org/10.5281/zenodo.1002374

The traditional pest monitoring methods is a labor-intensive and time-consuming work which can't meet the requirements of modern precision agriculture. In order to realize the dynamic monitoring and forecasting of vegetable pests and provide information support for the development of precision agriculture, it has become an inevitable trend to realize the fast, safe and reliable transmission of pest information collection. In this paper, a comprehensive monitoring and early warning system of vegetable pest based on internet of things (IOT) is designed. The system includes farmland environment data acquisition system (EDAS), vegetable pest image data acquisition system (VPIDAS) and vegetable pest monitoring and early warning platform. The EDAS uses commercial environmental sensors to collect farmland environmental data. The VPIDAS is self-developed, this system combines the technologies of machine vision, telematics and solar power technology, and can obtain the image data of vegetable pests for a long time. The Vegetable pest monitoring and forecasting platform is used to manage the data acquisition system, and analyze the collected data to provide information support for forecasting and early warning of vegetable pests. Users can interact with the platform via Internet with a PC, management of data collection, analysis of the collected data and prediction of vegetable pests early warning. A series of real test-beds show that the monitoring system can work steadily and reliably, and has wide application prospect.

Poster

Design and experiment of online mixing spraying system

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http://doi.org/10.5281/zenodo.1002382

Background: The widely-used online mixing system has a small range of mixture ratio and a detection problem at small flow ratio of pesticide. This paper developed an online-mixing system, which mixed pesticide into carrier directly.

Methods: The pesticide were injected to the mixer from pesticide tang through a piston pump, witch controlled by stepper motor. A solenoid valve was used to control water flow into the buffer tank; the water level of the buffer tank was controlled using two liquid level sensor feedback. The water flow rate of the spray pump from the buffer tank was measured using a turbine flowmeter. According to the water flow rate, the proportion of pesticide was injected into the mixer with water together. The mixture of pesticide and water was sprayed to the target.

Results: During the spraying, water and pesticide was measured at the same time, the maximum error of the mixture ratio was 6.75%. The maximum error of mixture uniformity was 6.33%, and the variation coefficient was 7.91%.

Discussion: The system proposed supplied the water and pesticide in proportion, and the range of the mixture ratio was 100:1 ~ 1000:1, it can satisfy the requirements of spraying in paddy field.

Conclusion: The experiment was used the cochineal solution as the pesticide, the next step will be to carry out field experiments with real pesticides.

Poster

Wireless soil sampling and recording system based on Android

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http://doi.org/10.5281/zenodo.1002315

The paper presents an automatic method for recording soil sampling information, which is suitable for modern agriculture. The wireless automatic sampling and recording soil information system is developed based on Android system combined with the remote server and database architecture. Tencent CentOS 6.5 64 bit cloud server was used in the system. Android 7 Nougat intelligent platform was used as the client. Then the feasibility and demand analysis of the whole system were completed.

Poster

On-line modeling of tractor pitch angle based on ARMA

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http://doi.org/10.5281/zenodo.1002259

Background: The working quality and efficiency of agricultural machinery are largely dependent on the bottom-layer flatness of paddy fields. There are various kinds of profiling mechanism which are designed for the attitude adjustment of agricultural implement, however, response rate is still limited to the control and performing system.

Methods: An on-line modelling approach based on the time-series theory was put forward as a method to predict attitudes of tractor within 1-2 seconds. An AHRS (Attitude and heading reference system, Mti-300) was installed on the tractor to obtain attitudes in real time. The steps to build a time-series model mainly include: data processing, model identification as well as parameters estimation. By taking the difference to the non-stationary data acquired in the field, a set of stationary time-series was created for modelling. The AIC (Akaike information criterion) method was adopted to determine the model order, and the RLS (Recursive least square) algorithm was applied in model parameter-estimated on line. The estimated model is considered adequate to make prediction if residuals of the model are free from autocorrelation. The performance of the model can be validated by making the comparison between predicting values and sensor measurements with RMSE (Root mean square error).

Results: AR(10) model was found to follow the dynamic trend of tractor roll angle (10Hz) better, thus a 10-step (1s) prediction was conducted utilizing Matlab, and then continuing with the same loop iteration, a set of 30s prediction was finished with the RMSE less than 2°.

Discussions: The accuracy of the prediction satisfies most of attitude adjustment of tractors and the algorithm can be used in more agricultural situations.

Conclusion: The algorithm was tested and simulated merely with the roll angle data, and the prediction of three-axis attitude needs further study.

Poster

System development for potato crop growth management

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http://doi.org/10.5281/zenodo.1002273

In order to improve the information service levels of potato crop growth management, a potato crop growth management system was developed to monitor potato crop growth information and provide expert guidance and assistance to users for potato cultivation. The users can access the system platform through the mobile terminal. In early researches, potato crop monitoring sensors were developed and used to collect the potato crop information in the field. The system builds a basic data management platform, which mainly provides information support for different growth periods of potato crops. At the same time the user can analyze the current crop growth according to the displayed data, thus significantly improving production efficiency. The results showed that the system has user-friendly interfaces and reasonable design of the system. The system can basically reach the level of agricultural information technology application.

Keynote

Research and application of plant protection techniques and implements for rice production in China

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http://doi.org/10.5281/zenodo.1002899

Rice plant protection is an essential part of the rice production. In order to achieve sustainable agricultural development and ensure national food and ecological security, there is important significance to improve the utilization of agricultural resources and enhance the control capabilities of the sudden area-wide pest infestation. Based on the review of the current status and existing problems of Rice Plant Protection Machinery (RPPM) in China, including manpower spraying equipment, small power plant protection machinery, large and medium-sized power plant protection machinery, and aviation application, the urgent needs of the new precise and efficient paddy pesticide spraying machinery in modern agricultural production were discussed. And then the future directions of RPPM were pointed out, which includes the precision spraying and efficient spraying. Finally, the countermeasures to promote the rapid development of RPPM were put forward, which including broaden the coverage of a single spraying operation, strengthening the method innovation of paddy spraying, and vigorously promote the application of aviation plant protection